THE AUTHORITY ON THE FUTURE OF TECHNOLOGY

January/February 2007
www.technologyreview.com

Technology Review

PUBLISHED BY MIT SINCE 1899

Special Software Issue

Anything You Can Do, I Can Do Meta

Charles Simonyi designed Microsoft Office. Now he wants to reprogram software.

BY SCOTT ROSENBERG Page 36

Simonyi is headed for outer space on April 9.

Technology Review's

Emerging Technologies Conference at MIT

Register Now for 2007 & Save $400

Technology Review's Emerging Technologies Conference at MIT brings you remarkable technological breakthroughs that will transform the way we live and do business. This unique event brings together business leaders, venture capitalists, senior technologists, and a remarkable group of the top 35 innovators under the age of 35—the TR35.

Join us in September 2007 for three action-packed days on the MIT campus. The conference program includes presentations from world-renowned business leaders, panel discussions with today's top innovators, demonstrations from leading companies, and unparalleled networking opportunities with the people you need to meet in the technology industry. If you are in charge of the strategic direction of your company or simply passionate about technology, this is an event you cannot afford to miss.

Register now to lock in a full-conference pass for just $995, a $400 savings (on-site $1,395).

REGISTRATION OPTIONS

CONFERENCE PACKAGES	**Early Bird** Before 8/1/07	**Standard** After 8/1/07	**On-site** After 9/24/07
Full Conference Pass	$995	$1,295	$1,395
One-Day Pass	$495	$695	$795

Group Discount: 20% discount for groups of 3 or more.

TO REGISTER

Visit: **www.technologyreview.com/reg1**
For questions, e-mail: etcinfo@technologyreview.com
or call: 617-475-8077

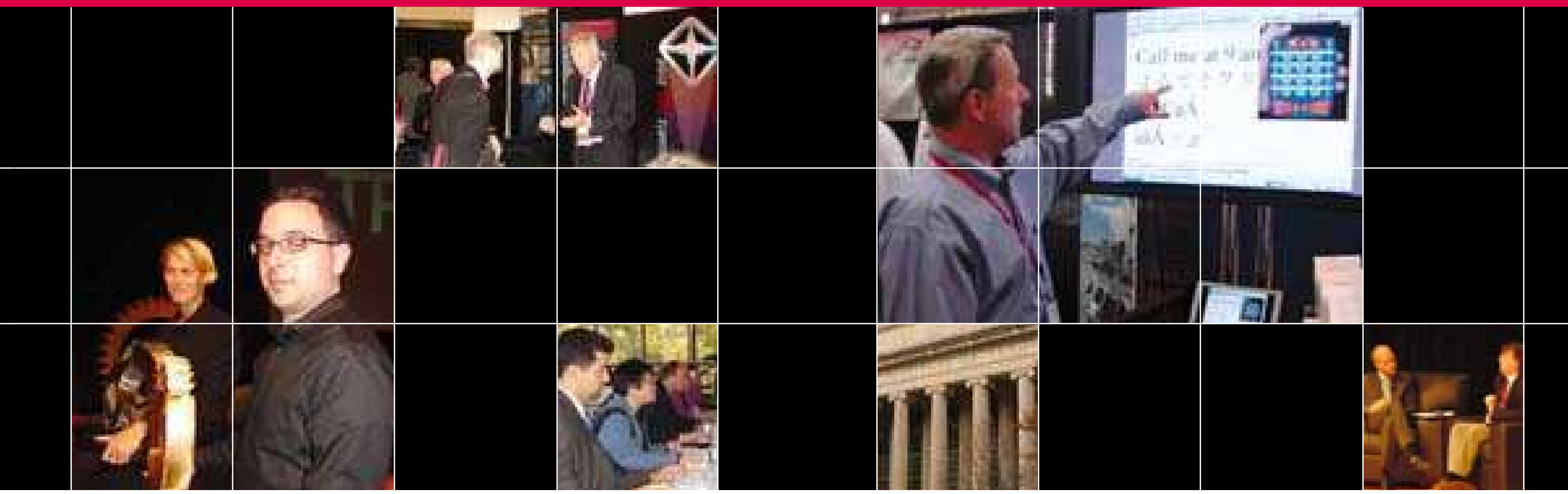
TO SPONSOR OR EXHIBIT

Connect directly with this important audience of business leaders, venture capitalists, and technology innovators. For program details, visit:
www.technologyreview.com/events/tretc/sponsor.aspx

E-mail: sponsorship@technologyreview.com

Sign up now and save:
www.technologyreview.com/reg1

September 25-27, 2007
MIT Campus



Join us Sept. 25-27, 2007 for the chance to meet the innovators and industry leaders who are shaping the future of technology. Highlights include:

TR35—Young Innovators Under 35

Meet the next generation of technology leaders and discover how they will change our world. Past recipients include Sergey Brin and Larry Page, Google; Helen Grenier, iRobot; and Joshua Schachter, Del.icio.us (Yahoo).

Emerging Technologies Showcase

Cutting-edge advances and innovations featured by leading companies. This showcase exhibits the next generation of technologies, plus prototypes, designs, and interactive experiences.

TR35 Call for Nominations

Help us find the next generation of technology pioneers and tell their stories!

Nominations are now open for the 2007 TR35, *Technology Review*'s list of 35 young people whose contributions to emerging technologies are poised to profoundly change our world. Nominees should not turn 35 before October 1, 2007, and their work should exemplify innovation in fields such as biotechnology, computing, energy, medicine, nanotechnology, telecommunications, and transportation.

Technology Review will feature the TR35 in the September/October 2007 issue and recognize them at the 2007 Emerging Technologies Conference at MIT.

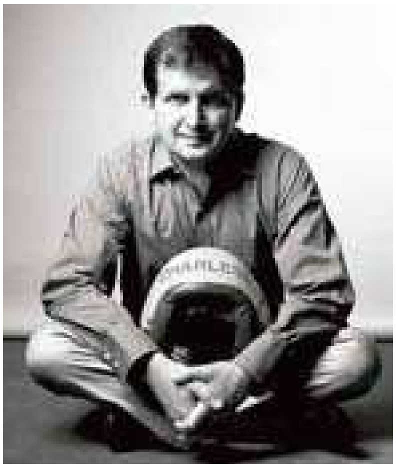
The deadline for nominations is March 1, 2007.
To nominate, visit:

www.technologyreview.com/tr35/nominate.aspx

To nominate the TR35:
www.technologyreview.com/tr35/nominate.aspx

Contents

Volume 110, Number 1



Cover photo by Brian Smale

Technology Review

PUBLISHED BY MIT

Editor in Chief and Publisher
Jason Pontin

Editorial

Editor
David Rotman

Deputy Editor
Nate Nickerson

Art Director
Lee Caulfield

Chief Correspondent
David Talbot

Senior Editor
Erika Jonietz

Senior Editor, MIT News
Alice Dragoon

Biotechnology and Life Sciences Editor
Emily Singer

Information Technology and Computer Science Editor
Kate Greene

Nanotechnology and Materials Science Editor
Kevin Bullis

Copy Chief
Linda Lowenthal

Copy Editor
Larry Hardesty

Research Editor
Jessica B. Baker

Assistant Editor
Katherine Bourzac

Production Consultant
James LaBelle

Contributing Editor
Wade Roush

Contributing Writers
Peter Fairley, Simson Garfinkel, Stephan Herrera, Charles C. Mann, Michael Schrage, Mark Williams

Assistant Designer
Angela Tieri

technologyreview.com

Web Producer
David Foucher

Managing Editor
Rachel Ross

Web Copy Editor
Nell Beram

Web Developers
Shaun Calhoun, Michael Callahan, Sarah Redman

Web Production Assistant
Brittany Sauser

Corporate

Chief Financial Officer
Rick Crowley

Chief Operating Officer
James Coyle

Executive Assistant
Leila Snyder

Manager of Information Technology
Colby Wheeler

Marketing

Senior Vice President, Business Development and Marketing
Kathleen Kennedy

Senior Graphic Designer
Matthew Bouchard

Marketing Communications Manager
Stephanie Corner

Advertising Services Coördinator
Jennifer Yang

Sales and Marketing Coördinator
Amy Lammers

Consumer Marketing

Circulation Director
Heather Holmes

Fulfillment Manager
Tina Bellomy

Finance

Accountants
Letitia Trecartin, John Foley

Board of Directors

Reid Ashe, Allan S. Bufferd, Jerome I. Friedman, Elizabeth A. Garvin, Sherwin Greenblatt, Robert M. Metcalfe, Ann J. Wolpert

Relaunch Fund

Millennial Patron
Robert M. Metcalfe

Centennial Patrons
Steve Kirsch, DuWayne J. Peterson Jr.

Customer service and subscription inquiries

National: 800-877-5230
International: 386-447-6352
www.technologyreview.com/customerservice
Permissions: 978-750-8400
Reprints: 717-399-1900 x118
MIT Records: 617-253-8270 (alums only)

Advertising Sales

Senior Vice President and Director of Advertising Sales
Maureen Elmaleh
maureen.elmaleh@technologyreview.com
212-419-2823

New England and Eastern Canada
Barry Echavarria
barry.echavarria@technologyreview.com
603-924-7586

Northeast
NEW YORK
Clive Bullard
cbullards@cs.com
845-231-0846

Northwest Sales Manager
Patrick Viera
patrick.viera@technologyreview.com
415-659-2982

Northwest
SAN FRANCISCO
Steve Thompson
stevet@mediacentricinc.com
415-435-4678

Southwest
DALLAS
Steve Tierney
steve.tierney@tierney.com
972-625-6688

France
Philippe Marquezy
philippe.marquezy@espacequadri.com
33-1-4270-0008

Germany
Karl-Heinz Piotrowski
khp@technologyreview.de
49-511-5352-761

Europe
Anthony Fitzgerald
mail@afitzgerald.co.uk
44-1488-680623

Israel
Dan Ehrlich
d_ehrlich@netvision.net.il
972-9-9586-245

China, Hong Kong, Philippines, and Thailand
Herb Moskowitz
mediarep@netnavigator.com
852-28-38-87-02

Japan
Shigeru Kobayashi
shig-koby@media-jac.co.jp
813-3261-4591

South Korea
S.Y. Jo
biscom@unitel.co.kr
82-27-39-78-40

Taiwan
Keith Lee
leekh@ms4.hinet.net
886-2-25-23-82-68

Online Advertising
Patrick Viera
patrick.viera@technologyreview.com
415-659-2982

Technology Review
One Main Street, 7th Floor
Cambridge MA 02142
Tel: 617-475-8000
Fax: 617-475-8043

De Technologia non multum scimus. Scimus autem, quid nobis placeat.

Technology Review, Inc. is the authority on the future of technology, identifying emerging technologies and analyzing their impact for technology leaders. An independent media company owned by the Massachusetts Institute of Technology, Technology Review, Inc. publishes the daily technology news website technologyreview.com and *Technology Review* magazine, the oldest technology magazine in the world (founded in 1899). Technology Review, Inc. also produces live events such as the Emerging Technologies Conference. The views expressed on technologyreview.com, in *Technology Review*, and at our events are not necessarily those of MIT.


Services not available in all areas. Subject to applicable restrictions, tariffs and service agreements. Contact Qwest for details. © 2007 Qwest. All Rights Reserved.
Is your network ready
to grow as fast as you are?
When your company grows, your network should scale
with it. We call it being nimble. It's why we offer nationwide
network, data and voice solutions that evolve as your needs do.
And it's why 95 percent of Fortune 500® companies choose Qwest.®
Get Qwest. Get Nimble. Call 1 888-658-5655 or visit qwest.com/business.
QWEST
BUSINESS
SOLUTIONS
Qwest
Spirit of Service®

Contributors

Peter Fairley visited China to report on efforts there to deploy coal gasification technologies on a large scale *("China's Coal Future," p. 56)*. China hopes that gasification will mitigate its growing dependence on foreign oil while reducing pollution. And pollution in China, Fairley found, is intense. "In cities like Zaozhuang—which is about halfway between

Shanghai and Beijing in Shandong province—where I visited an innovative gasification plant, the air pollution from the pulverized-coal-fired power plants appears to literally descend in sheets," he says. "And during my afternoon of reporting in Shandong province, I found my inhalations shortening. It was like my body had taken it upon itself to protect me and was trying to escape the inescapable." Fairley has covered energy technologies for such publications as the *Sunday Times* of London, *IEEE Spectrum*, and *Popular Mechanics*.

Scott Rosenberg is the author of *Dreaming in Code: Two Dozen Programmers, Three Years, 4,732 Bugs, and One Quest for Transcendent Software*, to be published by Crown in January 2007. The book tells the story of a group of programmers, led by Lotus 1-2-3 creator Mitch Kapor, intent on building a personal information manager better than Microsoft's Outlook. (The book is excerpted on pages 46 and 47.) For this month's cover story *("Anything You Can Do, I Can Do Meta," p. 36)*, Rosenberg profiles former Microsoft chief architect Charles Simonyi, whom Bill Gates has called "one of the great programmers of all time." Simonyi is now on a mission to reform software, and to that end, he has founded a company called Intentional Software. "I already knew about Simonyi and Intentional Software and wrote a bit about them in my book, but for various reasons I hadn't interviewed him in depth,"

Rosenberg explains. "So the opportunity to profile him for *Technology Review* was irresistible. I didn't know about his planned space shot until after I started researching the piece, though. If only his trip had been timed for before my deadline, I could have interviewed him in orbit! Then I think I could feel my career was complete." In the early 1990s, Rosenberg moved from being a theater and movie critic at the *San Francisco Examiner* to being a technology writer. In 1995, he left the *Examiner* to help start Salon.com, where he is now vice president for new projects.

Corby Kummer wrote this month's essay on chef Grant Achatz and the intersection of technology and high cuisine *("The Alchemist," p. 62)*. We

gave Kummer, who writes about food for the *Atlantic*, this assignment out of curiosity: what, we wondered, would the author of *Slow Food*—which explores a culinary and social movement that champions food simply prepared and life simply lived—think of Alinea, Achatz's Chicago restaurant? (It's the kind of place where food isn't so much cooked as it is engineered.) "I was all ready to hate it," says Kummer, "having watched with progressive alarm chefs torment perfectly good, innocent food into whimpering submission with the pathetic excuse of forwarding the culinary arts. But eating at Alinea was as transformative for me as eating at El Bulli, the culinary madhouse north of Barcelona, is for fellow foodies. I was fascinated by what I ate, liked a lot of it, and was really seduced by a few dishes. It didn't turn me into a complete convert—I think most American disciples of the weird, novelty-as-all, El Bulli food go way overboard, and I'm not interested in dining at their lab benches, so to speak. But in the hands of someone as fiercely ambitious as Grant Achatz, I'm willing to put at least one foot into the future."

Lara Kastner photographed the preparation of hamachi at the Chicago restaurant Alinea for Corby

Kummer's essay on technology and cuisine (see above). Kastner is no stranger to Alinea's kitchen; she updates the restaurant's website with pictures of its interior and of the dishes on its menu. "The kitchen is impeccably clean at all times," she says, "like I'd imagine a lab would be, with its stark, white, tiled walls and stainless-steel countertops. There is rarely any chaos there. Or if there is, they don't let it show." Kastner's work has appeared in *Metropolis*, *Gourmet*, *Chicago* magazine, the *New York Times Magazine*, and other publications.

The November/December 2006 issue introduced a new feature to the magazine: the essay. Freeman Dyson's remembrance of his time spent working for Britain's Bomber Command in 1943–1945 ("A Failure of Intelligence") prompted many letters.

War Stories

I was a rear gunner flying Lancasters in 300 (Polish) Bomber Squadron, which flew alongside Britain's Royal Air Force and operated out of Britain. Reading Freeman Dyson's essay brings back many memories, not all of them pleasant. I share some of Dyson's views on the ruthlessness of Sir Arthur "Bomber" Harris, commander in chief of Britain's Bomber Command. My expression of the revulsion I felt when ordered to bomb Chemnitz, Germany, the day after Dresden was burnt—and after being told that the refugees from Dresden were filling the streets of Chemnitz, where there was no room in shelters—nearly got me court-martialed!

The night flying in "streams" was deadly! That is when we could have used an additional half-dozen eyes. The sight of glowing exhaust manifolds bearing in on you made your "fighter affiliation" exercises pay off. And on cloudy nights, the fear of collisions was such that at the end of each "leg," the planes in the stream would, before turning, switch on their navigation lights for a moment. It looked like a Christmas procession.

The Operation Manna flights, wherein Allied bombers were used to feed people in the Nazi-occupied Netherlands in 1945, were a blessing. I participated in four such flights. Recently, when I was talking to Delft University of Technology professor Hans Blok over dinner, the subject came up. I found myself describing the feeling of seeing hundreds of people on the roofs and balconies, waving flags and waiting for food. Professor Blok smiled, then floored me: he was one of them.

Roman Golicz
Clinton, CT

The Freeman Dyson essay took me back 62 years. In 1944–'45, I was in charge of a small Eighth Air Force radar unit in England, France, and Germany. It was part of the Micro-H system for guiding American and English bombers to their targets in Germany. I can still see, in my mind's eye, the fleets of bombers and other aircraft that flew over the channel when the weather cleared in late December 1944 to support our troops in the Battle of the Bulge.

While in England, I made the acquaintance of a navigator who flew in a Lancaster bomber. I have sent him the Dyson essay; it has brought back memories of those harrowing days to him.

Henry Sandler
Philadelphia, PA

Freeman Dyson's essay really struck a chord with me. Perhaps that's because a part of the essay reports on the effectiveness of electronic countermeasures used during World War II—a subject that aroused my curiosity long ago.

As a lieutenant in the United States Air Forces in England during the war, I enjoyed working on extra-secret radar countermeasures, but I was never able to tell whether or not my efforts were producing the desired results. Although Dyson studied the Royal Air Force, I think his results also apply to the countermeasures used by the USAF.

Bill Hagenbuch
Beavercreek, OH

The first major European client of my consulting firm, Bonner and Moore, was Union Rheinische Braunkohlen Kraftstoff (URBK), in Wesseling, Germany. URBK operated a refinery and petrochemical plant built around a German synthetic-fuel plant from World War II. The layout of the original plant was a T, with the power plant at the bottom of the T and the high-pressure reactors at the intersection of the two legs. The top leg consisted of product purification units. After about three years of my association with URBK, enough trust had developed between us that they showed me their production records from the war.

What became clear to me was how effectively the plant withstood the many bombing attacks by British and American airplanes. These attacks concentrated on the center of the plant, which consisted of the high-pressure units and their associated compressors. The vessel and piping walls of these units were so thick that bombs had little effect. Only near the end of the war was an attack directed at the control room of the power plant. This attack by B-25s finally shut the plant for the remaining months.

Joe F. Moore
Houston, TX

One facet of war that Dyson's essay underlines is the enormous reduction in casualties, including civilian casualties, that has been brought about by the application of technology to the battlefield. Smart bombs and missiles, unmanned drones, and satellites and information networks enable the application of both offensive and defensive power with casualties that pale beside those in previous conflicts. One casualty is a tragedy, but we can be thankful that when it's necessary to defend or project the nation's interests with armed force, it will be with far less human cost than previously.

Mike Boylan
Houston, TX

How to contact us

E-mail letters@technologyreview.com
Write *Technology Review*, One Main Street, 7th Floor, Cambridge MA 02142
Fax 617-475-8043
Please include your address, telephone number, and e-mail address. Letters may be edited for both clarity and length.

I was surprised that the renowned scientist Freeman Dyson omitted the key facts that determined why the United States, Great Britain, and Russia were victorious over Germany and Japan in World War II. It was because they fought to win as quickly as possible—and to reduce their own casualties by destroying the enemy's ability to fight. Dresden wasn't making cuckoo clocks. It manufactured war materials and was a major transportation center.

The idea that the bombing of Dresden was an excessive use of force, that it caused too many casualties among German civilians too near the end of the war, is nonsense. The war's end in Europe came because of such drastic actions, just as the end of the war with Japan came because of the atomic bombing of Hiroshima and Nagasaki.

In all of history, no nation has been victorious by fighting a more gentle war than its enemy, as Dyson now suggests should have been done against Nazi Germany. The facts are that the victorious side in war has always used its power to win as quickly and conclusively as possible.

William Lyons
Irvington-on-Hudson, NY

One Laptop per Child?

No, the $100 laptop will not save the world *("Philanthropy's New Prototype," November/December 2006)*. Millions of $100 laptops already exist; you probably own one yourself—the four-year-old Dell collecting dust in your closet that won't sell on Craigslist for $100—and it isn't being used to save the world.

Government money comes from its citizens. If the citizens aren't willing to spend their own money for the laptop, it makes even less sense for them to pay taxes so the government can act as a third-party laptop distributor.

The solution for impoverished countries is to reduce government and taxes, allow free-trade democracy, and let the population build its own capitalistic economy.

William J. Arora
Cambridge, MA

Electronic Voting

Your piece about Princeton University computer scientists hacking a Diebold voting machine *("How to Steal an Election," November/December 2006)* demonstrates a problem with a particular electronic voting machine but doesn't articulate the corollary: voting security must be simple enough to be understood by the poll watchers who safeguard the vote count.

With paper ballots, volunteers at polling stations follow an easy procedure: verify that the ballot box is initially empty, watch the voters place ballots in the box, and watch as the box is opened and the votes counted.

With electronic voting, poll watchers must instead ensure that the

voting-machine software has not been tampered with. Volunteers might know nothing about computers but must protect against fraud by hackers, employees of the voting-machine manufacturer, and the government officials operating the polling stations.

Electronic voting isn't just an abstract computer security exercise; it must be secure when its guardians are nontechnical volunteers.

Irwin Jungreis
Sudbury, MA

Be Nice!

I paid special attention to Simson Garfinkel's article about using technology—in the form of a chip that, roughly speaking, does for a car what a flight data recorder does for an airplane—to "spy" on his wife's (and his own) driving behavior *("Spying On My Wife," November/December 2006)*. I had recently been cited for "careless" driving because of an accident caused by a driver who made an aggressive lane change and slammed on his brakes. The "physical evidence" led the responding police officer to conclude that the fault was mine. The other driver had a chance to do the right thing by telling the truth and accepting the blame. Instead, he shifted the blame to me through a false statement.

I paid a small fine and the deductible on my insurance, a small price compared to the other driver's loss of the respect of his three passengers. If Garfinkel is ever "at fault," I would hope that he would do the right thing rather than, as he claims he would, deliberately lose his chip—and his self-respect as well.

John W. Mohr
Saint Charles, MO

In Praise of Print

I'm just writing to provide some positive feedback on your decision to keep the print edition and, moreover, to add essays to it *("From the Editor," November/December 2006)*. I'm convinced that if the technology of written media had somehow developed in reverse, after centuries of reading articles on the Web, we would have heralded the invention of the printed magazine as a revolutionary breakthrough. Portable, high contrast ratio, resolution beyond the limits of human vision, and the ultimate in a tactile, flexible interface. *Technology Review* would be filled with articles trumpeting the end of the drudgery of scrolling through pixelated articles shackled to heavy devices, and humanity's liberation by the invention of "multilayer nano-imprinted organic media." It would spawn a print bubble in the stock market. Too bad such a good thing suffers from being invented too long ago to be sufficiently appreciated. But I say, Keep it.

Jonathan R. Birge
Cambridge, MA

From the Editor

On Rules

Strict and simple conventions favor the useful expression of ideas.

On Friday, April 6, 1327, during Easter mass in the Church of St. Claire in Avignon, Francesco Petrarca beheld the woman he would commemorate as Laura, and irrevocably fell in love. Petrarch was 23 years old. If literary tradition is correct in identifying the object of his *coup de foudre* as Laura de Noves, she was 17.

Petrarch probably never met Laura; she refused to see him because she was already married. But by the time he died in 1374, he had composed hundreds poems extolling her beauty, bemoaning his misfortune, and mourning her early death at the age of 38, a respectable mother of 11.

The poems are collected in a book commonly called *Il Canzoniere*, or "The Song Book." To praise Laura, Petrarch perfected the lyric form called the sonnet, which in his hands consists of 14 lines, usually of hendecasyllables, rhyming *abba*, *abba*, *cdc*, *dcd* or some other variation. This crabbed little form has been imitated by thousands of poets and has inspired many celebrated examples of literary art. The Petrarchan sonnet has been called a cage, but it is a cage that captures a peculiar economy of thought: the octave, the first eight lines, offers a proposition of some sort that is satisfyingly resolved in the sestet, the last six lines. The rules of a sonnet are strict but simple.

By contrast, consider the C++ programming language.

A program, like a poem, is a form for expressing ideas: in one case, words in a natural language, constrained within a lyric, express a man's love for a pretty woman; in the other, computer code, bound by the syntactical conventions of a programming language, express the idea, say, that an extraterrestrial robot like the Mars Rover could have an autonomous, embedded driving system.

C++ is arguably the most influential language of the last 25 years; many of the systems and applications of the personal-computer and Internet eras were written in it, including Google's search engine and the electronic switching systems that underlie our telecommunications networks. But for all that, C++ is notoriously hard to learn and use. Partly, this is owing to the difficulty of mastering the language's paradigmatic method, called "object-oriented programming." But mainly it is because software developers are free to express their ideas in C++ in a bewildering variety of forms.

In *The Design and Evolution of C++*, the language's inventor, Bjarne Stroustrup (whom we interview in this special issue on software; see "The Problem with Programming," p. 22), explains that he designed the language this way for quasi-philosophical reasons: "I find Kierkegaard's almost fanatical concern for the individual much more appealing than the grandiose schemes for humanity of Hegel and Marx. ... Often, when I was tempted to outlaw a feature I disliked, I refrained from doing so because I did not think I had the right to force my views on others."

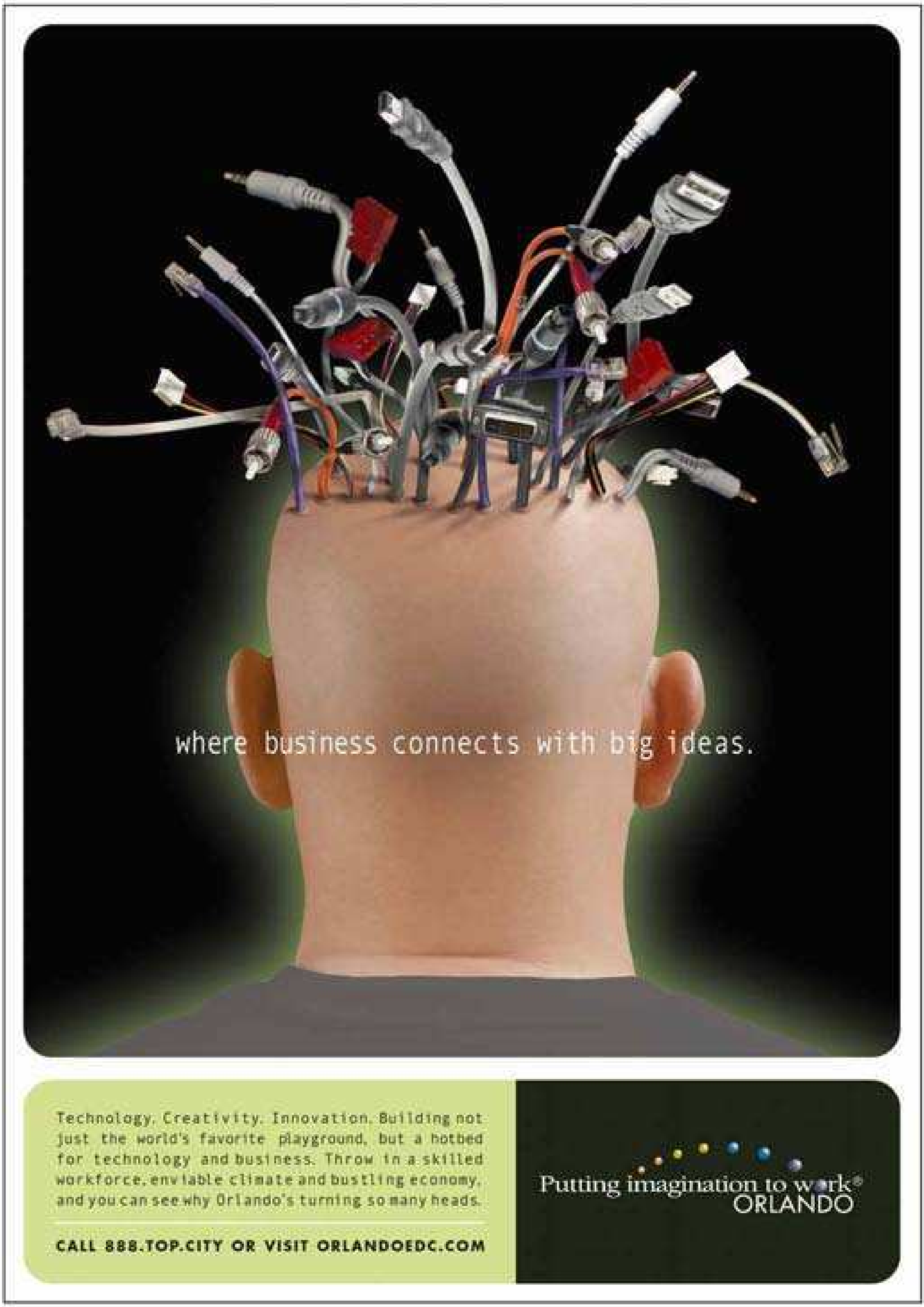
Stroustrup's restraint hasn't pleased the generations of programmers who have struggled with C++'s quirks of syntax and "features overload" (to use coder's jargon). When a version of our interview with Stroustrup was posted on Slashdot, an aggregator website that offers "news for nerds," it attracted 605 comments. "JCR" asked, "Why does C++ introduce so much complexity for so little benefit?" The rules of C++ are complicated but lax.

Programming languages affect more people than professional coders. Although our technological civilization runs on software, the software doesn't work very well. As our cover story by Scott Rosenberg puts it, "Everywhere you look, software is over budget, behind schedule, insecure, unreliable, and hard to use" *(see "Anything You Can Do, I Can Do Meta," p. 36)*. Excessively complicated programming languages, of which C++ is one example, are a major reason for software's confusion. This is because a useful programming language should be what computer scientists call an "abstraction" of the underlying complexity of control flows and data structures. C++ preserves for programmers the maximum possible freedom of expression; but as "JLeslie" (another Slashdot commentator) admitted, "The cost was that it wasn't much of an abstraction."

There may be another way. Charles Simonyi, the former chief architect of Microsoft, who is now the chief of Intentional Software, wants to overthrow programming languages for something he calls "intentional programming." Rosenberg's profile of Simonyi explains how intentional programming might give developers a higher order of abstraction. Rather than writing software code in programming languages, programmers would gratefully relinquish the production of code to a "generator" that would swallow their designs, representing the intentions of computer users, and spit out working code in a language that computers could understand, compile, and run.

The best expression of ideas occurs in forms that are strict and simple. Could Charles Simonyi be offering programmers a new form that is at once easier and more rigorous than anything they have had before? Write and tell me at jason.pontin@technologyreview.com. **Jason Pontin**

MARK OSTOW


where business connects with big ideas.
Technology. Creativity. Innovation. Building not just the world's favorite playground, but a hotbed for technology and business. Throw in a skilled workforce, enviable climate and bustling economy, and you can see why Orlando's turning so many heads.
CALL 888.TOP.CITY OR VISIT ORLANDOEDC.COM
Putting imagination to work®
ORLANDO

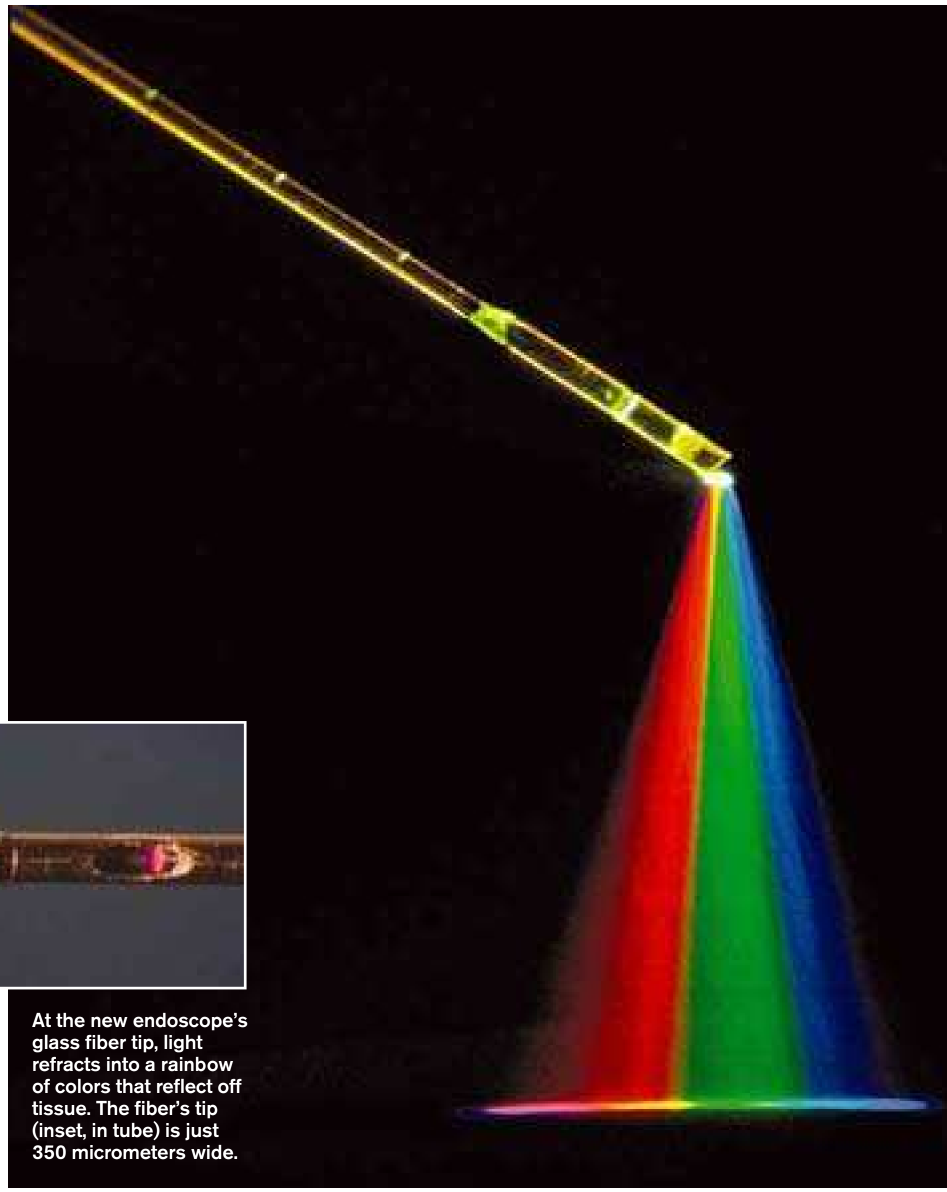
Forward

MEDICINE

Superthin 3-D Endoscope

In an endoscope meant to penetrate the brain, look at a fetus, or thread through tiny ducts, smaller is better. But the endoscopes that produce the clearest 3-D images use cameras several millimeters wide—too big to go many places in the body. Now researchers at Massachusetts General Hospital in Boston have demonstrated an endoscope that's just 350 micrometers wide and sends back 3-D images that are as clear as those produced by larger endoscopes.

The key to the device is how it uses light, says Guillermo Tearney, professor of pathology at Harvard Medical School and the project leader. In the endoscope, white light moves down a glass fiber and is broken into a rainbow of colors by an optical device called a diffraction grating. Each color hits a different part of the tissue being imaged, reflects back, and travels through the fiber to a spectrometer outside the patient's body. Each color provides a separate pixel of information. A computer compares the reflections with a reference beam to create a 3-D topography.



At the new endoscope's glass fiber tip, light refracts into a rainbow of colors that reflect off tissue. The fiber's tip (inset, in tube) is just 350 micrometers wide.

COURTESY OF THE WELLMAN CENTER FOR PHOTOMEDICINE, MASSACHUSETTS GENERAL HOSPITAL

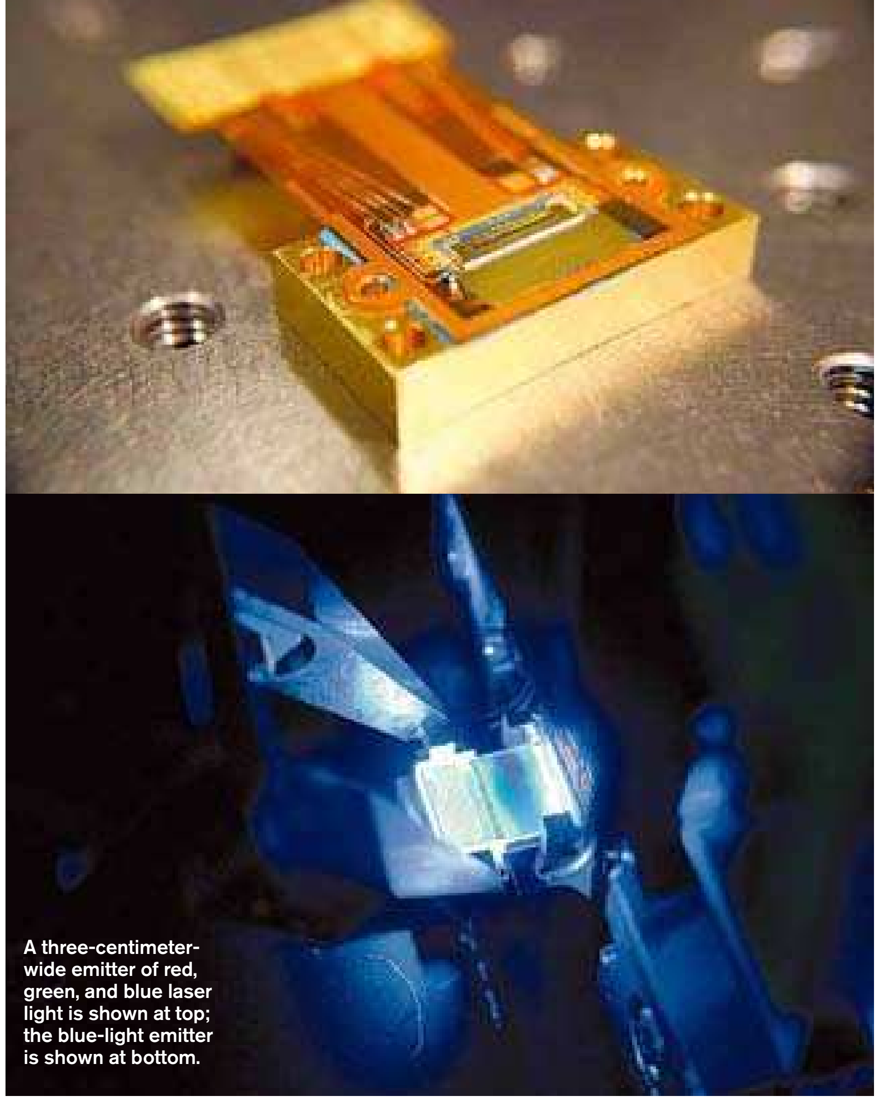
The scope's scans of a mouse abdomen showed 100-micrometer tumors on the abdominal wall. If doctors could see tumors that small in humans, they might catch cases of breast, pancreatic, and other types of cancer sooner, Tearney says. The device could also make it possible to perform new types of brain surgery and fetal surgery.

The new endoscope, still a prototype, must undergo safety testing before reaching humans, Tearney says, and it provides only slightly better resolution than existing scopes. But new versions in the works might feature improvements that boost resolution tenfold. **Susan Nasr**

ENERGY

Fuel Cell for Coal

Solid-oxide fuel cells that use gasified coal as a hydrogen source are a good candidate for the power plants of the future, because they can operate cleanly at high efficiencies and large sizes. But among the challenges they face, high manufacturing costs loom large. Now, GE researchers have demonstrated a method for assembling layers of ceramic and metal materials cheaply enough that a solid-oxide fuel cell system can be built for about $800 per kilowatt, which starts to approach the $500 to $550 per kilowatt of a conventional gas-fired plant. GE's six-kilowatt prototype (above) is a little more than two meters tall, with the fuel cell stack in the top section, and piping and control systems in the cooler lower section. The performance of the prototype suggests that a larger version could lead to gasified-coal-fueled power plants with greater than 50 percent efficiency, much better than the 35 percent efficiency of conventional plants. "I do believe GE has established a new state of the art," says Wayne Surdoval, technology manager for fuel cells at the National Energy Technology Laboratory. —*David Talbot*



A three-centimeter-wide emitter of red, green, and blue laser light is shown at top; the blue-light emitter is shown at bottom.

MATERIALS

Laser Television

Watch out, plasma TV lovers. Later this year, Mitsubishi and Samsung could be selling TVs that use lasers to provide more, and more accurate, colors than other display technologies do. That even goes for plasma displays, which use electrically charged gases to cause materials called phosphors to glow.

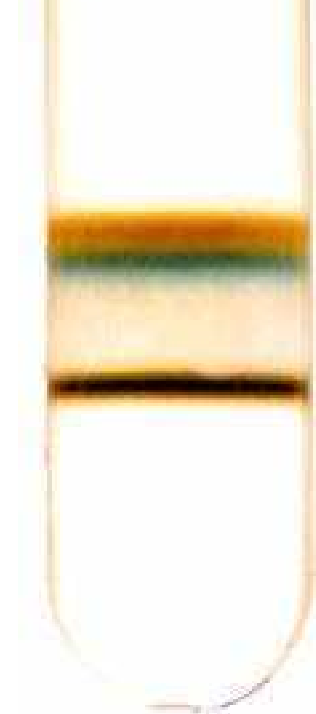
Lasers have always been theoretically better, but until recently, lasers small enough to fit in displays or projectors were too weak to be practical. But Novalux, a company in Sunnyvale, CA, found that adding a crystal of lithium niobate to a gallium indium arsenide laser would boost its light output and change its wavelength from infrared to the red, green, or blue that are the building blocks of color displays. The lasers shine on arrays of thousands of micromirrors that flip back and forth thousands of times a second to combine the light into new colors of different intensities, says inventor Aram Mooradian, founder of Novalux and former head of the quantum electronics group at MIT's Lincoln Laboratory.

The first commercial products to use the Novalux technology will be televisions that have 72 lasers each. But mobile gadgets that use as few as three lasers—say, cell phones that project photos on a barroom wall—could be next. Mooradian has his sights on Hollywood: ultimately he hopes to make movie projectors that use hundreds of lasers. **Kate Greene**

COURTESY OF GE (COAL); COURTESY OF NOVALUX (LASER)

NANOTECH

Nano Sorter



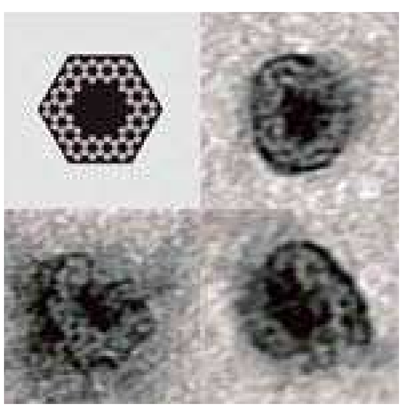
Carbon nanotubes could provide the circuitry for the computers of the future. But they can be either semiconducting or metallic, and the difficulty of getting the right type of tube in the right place on a computer chip has so far prevented their commercial use.

Now Northwestern University researchers have developed a way to separate nanotubes by electrical conductivity and by diameter, another property that's important for applications in electronics.

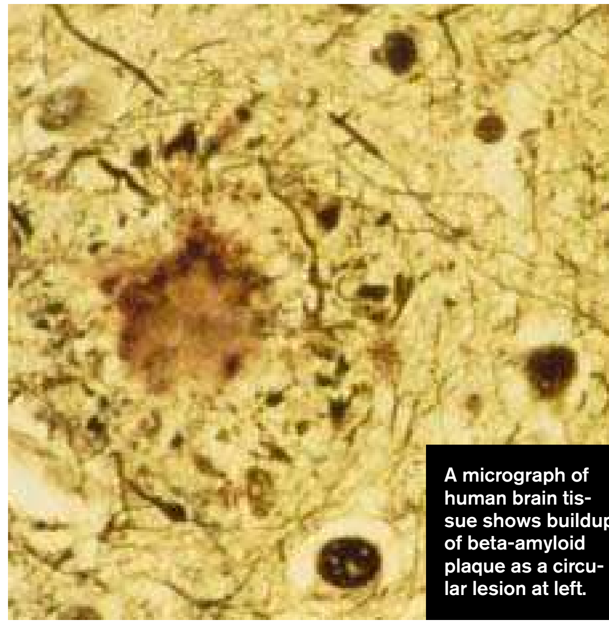
In the test tube at right, metallic nanotubes are shown in green and semiconducting tubes in orange. To separate them, the researchers add surfactants—chemicals common in detergents—to solutions of nanotubes. The surfactants cluster around the nanotubes in different concentrations and arrangements, depending on the nanotubes' sizes and electronic properties. The clusters have different densities, so spinning the solution at ultrafast speeds produces layers containing specific kinds of nanotubes. While the researchers expected to be able to sort nanotubes by diameter, the sorting by electronic type came as a surprise, says Mark Hersam, a professor of materials science and engineering at Northwestern. Richard Martel, a chemistry professor at the University of Montreal, calls the Northwestern researchers' new approach "a breakthrough in the field." *—Kevin Bullis*

NANOBIOTECH

Barrel of DNA



Harvard University researchers have built a barrel-like structure, 30 nanometers in diameter, out of a long strand of DNA. The researchers studded the strand with short, specially designed snippets of DNA that can bind back to the strand, but only at specific spots. Strategic placement of the snippets caused the molecule to fold into different shapes. In the graphic above (top left), each circle represents a bird's-eye view of a standing double helix. After the snippets are placed, the molecule folds to create a sheet, which then curves around on itself, creating a double-walled barrel (other images). E. William Shih, a Harvard biologist and a leader in DNA architecture, who supervised the work, says such a device could someday be used to deliver drugs to specific tissues, but he concedes that "there's still quite a bit of work to be done." *—Emily Singer*



A micrograph of human brain tissue shows buildup of beta-amyloid plaque as a circular lesion at left.

BIOTECH

New Push for Alzheimer's Vaccine

Researchers hope to one day treat Alzheimer's with vaccines that prevent or clear the buildup in the brain of a protein known as beta-amyloid. But an early clinical trial of one such vaccine, sponsored by Elan of Dublin, Ireland, was stopped in 2002 after some patients developed encephalitis, an inflammation of the brain. Later, autopsies showed that despite the inflammation, the vaccine did clear the toxic protein from the patients' brains.

The Elan vaccine used the beta-amyloid protein itself to induce an immune response. Now, the National Institute on Aging is sponsoring a new trial of an antibody-based therapy already used to treat immune disorders: intravenous injection of immunoglobulins. The therapy uses a mix of different antibodies, including some against amyloid. Because immunoglobulins have already been used to treat thousands of people with immune disease, scientists say they are unlikely to cause inflammatory problems.

"There is tremendous interest in this approach," says Neil Buckholtz, who leads the NIA's research on dementias of aging. Elan also has an antibody-based drug in clinical trials.

Emily Singer

COURTESY OF SHAWN DOUGLAS AND THE HARVARD IGEM TEAM (BARREL); COURTESY OF M. S. ARNOLD ET AL./NORTHWESTERN (NANO); SPL/PHOTO RESEARCHERS, INC. (ALZHEIMER'S)

INTERNET

When Online Met Offline

Traditional social-networking sites are great for connecting people with like interests; meetup.com, for example, helps facilitate real-world gatherings arranged by appointed organizers. The next wave of sites might bring people together at a wider array of local events—such as concerts—without the involvement of organizers. Boston-based HeyLetsGo uses technology developed by computer scientists from MIT's Media Lab and the Georgia Institute of Technology to scour the Web for listings of local events, which it combines with feeds from ticketing sites and posts by users themselves. Users link their online profiles to event listings, post messages about mutual interests, and, maybe, connect. Judith Donath, director of the sociable-media research group at MIT, says, "People like it, and I think the idea is solid." The hope, says cofounder Rebecca Xiong, is that with HeyLetsGo, "online is not separate from offline." The site plans rollouts in several U.S. cities this year. —*Karen Nitkin*

BIOTECH

RNAi's Drugs

Pharmaceutical giant Merck's purchase last fall of Sirna, a San Francisco biotech company specializing in RNA interference (RNAi), was just the latest indication that the technology is gaining momentum. Researchers are currently trying to use RNAi to do everything from treat flu to permanently remove hair. In RNAi therapy, small pieces of double-stranded RNA shut down the genes whose sequences they match. Below is a sampling of RNAi therapies under investigation. **Katherine Bourzac**

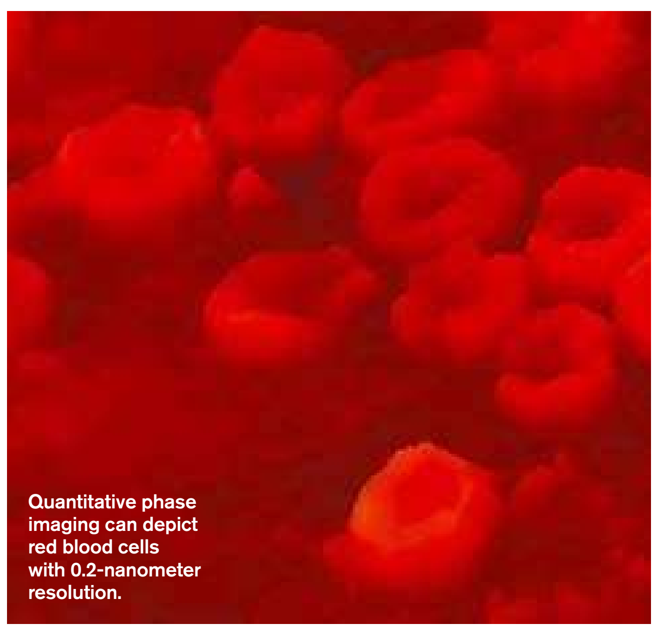
Disease/company	**Approach**	**Status**
Age-related macular degeneration *Acuity (Philadelphia, PA) and Sirna (San Francisco, CA)*	Eye injection of RNA that blocks a gene responsible for excessive growth of blood vessels	In phase II clinical trials
Viral lung infections *Alnylam (Cambridge, MA)*	Inhalation of drug containing RNA that shuts down viral genes	Therapy for respiratory syncytial virus in phase I trials
Parkinson's disease *Alnylam and Sirna*	Injection of RNA to block a gene that kills brain cells	In preclinical development
Huntington's disease *Sirna*	Injection of RNA to block a gene that kills brain cells	In preclinical development
Hair removal *Sirna*	Application of cream containing RNA that blocks hair growth genes	Application to begin clinical trials in progress

MEDICAL IMAGING

Eye on Cells

In physicist Michael Feld's MIT lab, researchers watch red blood cells vibrating and undulating in real time, thanks to a technology known as quantitative phase imaging. The technology splits a light wave in two, passes one wave through a cell, and then recombines it with the other wave.

Analyzing the resulting interference pattern provides a remarkable view of living, moving cells not possible with electron microscopy, which requires careful sample preparation. Researchers in Feld's lab are studying the dynamics of red blood cells' membranes to gain insight into diseases such as malaria, leukemia, and sickle-cell anemia. Others are studying neuron dynamics. And while the MIT group has produced images with an astonishing 0.2-nanometer resolution, Feld ultimately hopes to create 3-D images of the inner structures of living cells, too. —*Jennifer Chu*

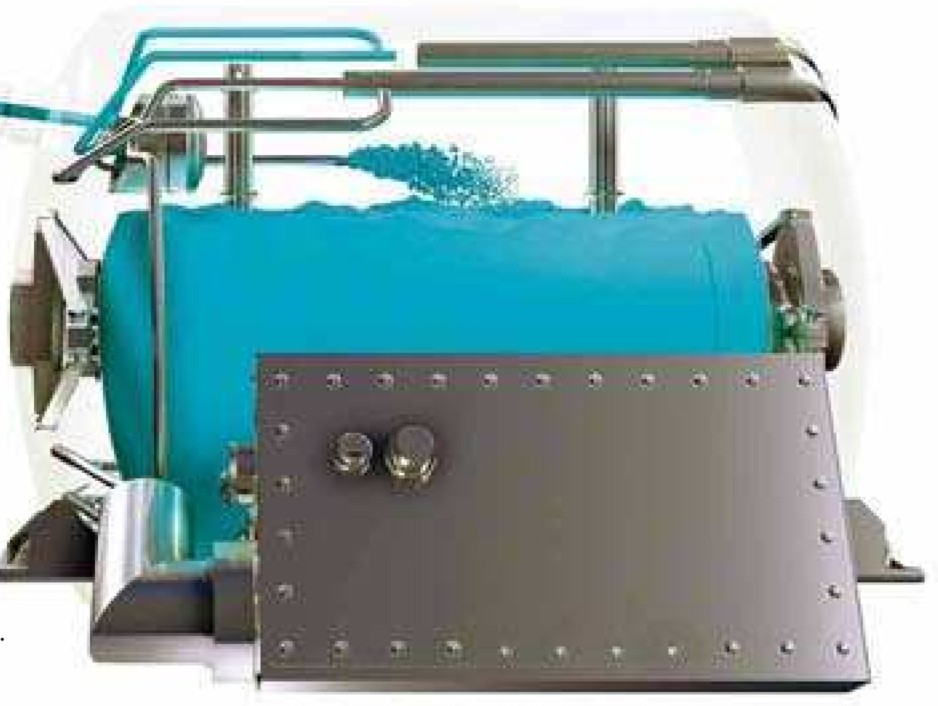


Quantitative phase imaging can depict red blood cells with 0.2-nanometer resolution.

LAURENT CILLUFFO (ONLINE); COURTESY OF GABRIEL POPESCU (CELLS)

TRANSPORTATION

Gassy Tank

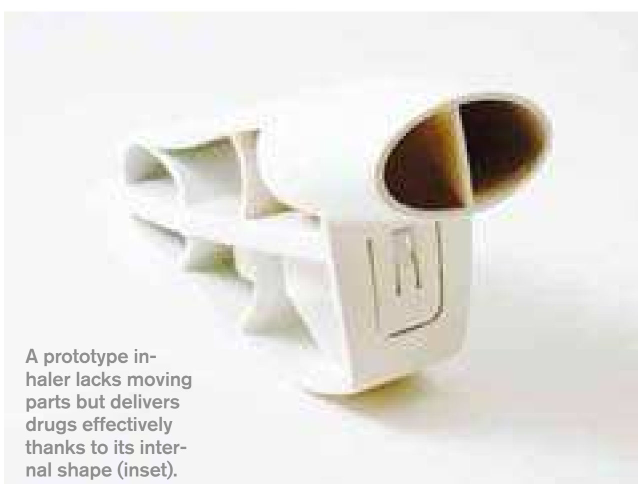


Next year, BMW plans to produce 100 luxury sedans that can burn liquid hydrogen in addition to gasoline. The hardest part of the job? Manufacturing the hydrogen tank (shown at right with the hydrogen-pump nozzle attached). The tank eats up half of a car's trunk space and weighs 167 kilograms. To keep hydrogen liquid—which ensures there's enough in the tank for a long drive—you need to chill it to –253 °C. So the tank has two walls of stainless steel separated by a vacuum and multiple layers of insulation. Despite the insulation, the liquid inevitably turns into a gas. After 17 hours, pressure rises sufficiently to make a valve open, venting hydrogen gas that a catalytic converter oxidizes into water vapor. A half-tank of hydrogen in an undriven car will largely "boil off" in nine days. The tank also has a second system that quickly vents hydrogen through the roof of the car if the tank is damaged in an accident. To be cautious until more testing can be done, BMW asks users not to park its hydrogen cars in enclosed garages. The company is seeking new technologies for automotive storage of liquid hydrogen, but for now, its tank seems to be the state of the art. **David Talbot**

MEDICINE

Four-Cent Inhaler

Drugmakers are increasingly turning to inhalable versions of vaccines and drugs in order to avoid the hassle and danger of syringes. A new inhaler that costs only four cents could administer powdered drugs as effectively as traditional inhalers that cost 10 times as much. The technology, which uses no moving parts, could help poor countries stop relying on syringes, which cost pennies apiece but require trained staff and carry an infection risk. To make their inhaler cheaper, engineers at Cambridge Consultants of Cambridge, England, and Boston focused on its internal shape. When a user inhales, a kind of miniature tornado forms inside the device, lifting a powdered drug into the air. The company is in talks with pharmaceutical firms to test the device with a powdered flu vaccine, among other drugs. Though an inhaler is a fraction of the price of a vaccine dose (currently \$3 to \$7), the savings could make a difference. "Everyone in the field dreams of a future with these kinds of simple, low-cost vaccine delivery systems," says Donald Francis, cofounder of Global Solutions for Infectious Diseases, a nonprofit vaccine developer. "Moving to a needle-free model is a goal most of us share." *—Tom Mashberg*



A prototype inhaler lacks moving parts but delivers drugs effectively thanks to its internal shape (inset).

COURTESY OF BMW (TANK); COURTESY OF CAMBRIDGE CONSULTANTS (INHALER)

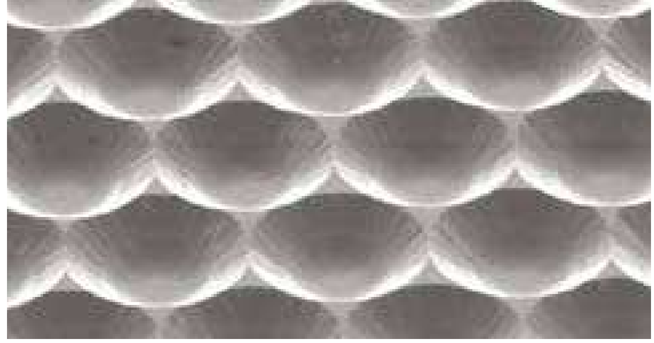
INTERNET

Vox Populi

About 12 million Americans keep blogs, according to a survey released last July by the Pew Internet and American Life Project. Even more people might blog if the technology weren't so public. After all, who wants to share a high-school-reunion video with stockbrokers in Istanbul or teenagers in Tokyo?

Privacy controls that let a blog's author decide who can view each post are a major feature of several new blogging platforms. Vox, a free Web-based service launched by the San Francisco blogging-software maker Six Apart, allows users to assign various privacy settings to each post. The software is free, but bloggers have to accept that an advertisement will follow each of their posts.

Six Apart was already making blog-publishing software when, in 2005, it acquired LiveJournal, which has one of the fiercest followings in the blogosphere, thanks partly to privacy settings that are now part of Vox. "Sometimes you only want your five best friends in the world to see a post, and you should be able to do that," writes Six Apart cofounder and president Mena Trott in her own blog. The Pew survey suggests that this desire is widespread: only 27 percent of U.S. bloggers told researchers that a major reason they blog is to change the way other people think. A larger group, 37 percent, cited staying in touch with family and friends. **Wade Roush**



MATERIALS

White OLEDs Brighten

Organic light-emitting diodes (OLEDs)—which already make color displays in mobile phones and other devices brighter and more efficient—have taken a step closer to competing as sources of white light, too. In an OLED, electricity running through thin layers of organic materials causes them to emit photons. But only half the photons make it out of the materials, and three-fifths of those get scattered to the edges. Stephen Forrest, a University of Michigan electrical engineer, and graduate student Yiru Sun came up with a trick for making the diodes brighter: they use imprint lithography to stamp a hexagonal array of lenses, each a few micrometers in diameter, into a polymer substrate (above). The lenses direct light outward rather than sideways, boosting light output by 70 percent. "It's a significant benefit," says Vladimir Bulović, co-head of MIT's Laboratory of Organic Optics and Electronics. "There's a lot of light in the OLED that never makes it out." Eventually, energy-efficient sheets of glowing plastic could replace traditional light bulbs. Forrest says that with directive lenses and other improvements, OLEDs could reach an output of 100 lumens per watt in a couple of years, which would be better than the 90 lumens per watt of fluorescent bulbs. Manufacturing costs would then be the major remaining hurdle. —*Neil Savage*

ENERGY

100 Solar Megawatts

When the 10-megawatt Bavaria Solarpark began operations at three German sites in 2004—with 62 acres of silicon panels able to power several thousand homes on sunny days—it was one of the largest photovoltaic plants in the world. Now, bolstered by high energy prices and government incentives, a new crop of photovoltaic power plants—including one that might produce 10 times as much electricity *(see table)*—are planned around the world. The market for solar cells is doubling every 18 to 24 months, says Michael Rogol, a solar-industry consultant. While thin-film solar technology is lighter—good for rooftop applications where weight is an issue—larger solar-power installations tend to use silicon-based technologies, which require less acreage and wiring for a given electrical output. —*Kevin Bullis*

Organization	Size/date	Location
Zhonghao New Energy Investment (Beijing, China)	Up to 100 megawatts by 2011	Dunhuang City, China
Acciona (Madrid, Spain)	62 megawatts by 2010	Moura, Portugal
SunEdison (Baltimore, MD) and SkyPower (Toronto, Ontario)	Up to 50 megawatts by the end of 2009	Three to five 10-megawatt sites in Ontario

COURTESY OF Y. SUN, S.R. FORREST, *JOURNAL OF APPLIED PHYSICS* 100, 073106 (OLED); JASON SCHNEIDER (VOX)

MIT INDUSTRIAL LIAISON PROGRAM

CONNECTING THE WORLD'S LEADING COMPANIES TO MIT

Call 617-253-2691

http://ilp-www.mit.edu

Massachusetts Institute of Technology

Hack

Ancient Text

Lisp is a very old computer language, and is still widely used.

By Daniel Turner

Lisp—the *list processor* language—is "the greatest single programming language ever designed," according to computer scientist Alan Kay. It was born in 1958 because John McCarthy, then an assistant professor at MIT, working on new tools for artificial-intelligence research, wanted a language in which one could write programs that would make logical inferences and deductions. Previous languages, including Fortran, were numeric, which made for powerful number-crunching. But Lisp made use of symbolic expressions, which treated both data (such as numbers) and code as objects that could be manipulated and evaluated. This enabled programmers to create conditional expressions—Lisp made possible the now-familiar "if-then-else" structure—and today Lisp is used as a "macro" language, allowing users of software such as Emacs to create their own mini-applications that can automate tasks. The text below, from page 13 of McCarthy's 1962 *Lisp 1.5 Programmer's Manual*, uses Lisp to define the function evalquote. For its elegance and profundity, Kay compared this piece of code to James Clerk Maxwell's four equations describing electricity and magnetism.

evalquote is defined by using two main functions, called eval and apply. apply handles a function and its arguments, while eval handles forms. Each of these functions also has another argument that is used as an association list for storing the values of bound variables and function names.

```
evalquote[fn;x] = apply[fn;x;NIL]
```

where

```
apply[fn;x;a] =
    [atom[fn] → [eq[fn;CAR] → caar[x];
                 eq[fn;CDR] → cdar[x];
                 eq[fn;CONS] → cons[car[x];cadr[x]];
                 eq[fn;ATOM] → atom[car[x]];
                 eq[fn;EQ] → eq[car[x];cadr[x]];
                 T → apply[eval[fn;a];x;a]];
```

A Evalquote

At Lisp's inception, evalquote was considered its main function. "Evalquote is universal in the same way a Turing machine is universal," says Guy L. Steele, a fellow at Sun Microsystems Laboratory. "Functions in Lisp are represented as symbolic expressions. That is, Lisp functions exist as descriptions of what to do when given data. Evalquote, then, takes the description of the function plus the data and then returns the result of what the described function would do with the data." The text here shows evalquote defined in terms of another universal function, apply. It shows how programmers can expand the language by defining functions in terms of other functions.

B Symbolic expressions

In Lisp, the algebraic expression "3+x" is represented by the symbolic expression "(+ 3 x)," which can itself be used in further expressions. This ability to pass expressions on lets Lisp work with algebra as well as hard-number mathematics. Previous programming languages did not handle variables nearly as well. CAR is a symbolic expression of a slightly different sort: it is the name of a function.

```
        eq[car[fn];LAMBDA] → eval[caddr[fn];pairlis[cadr[fn];x;a]];
        eq[car[fn];LABEL] → apply[caddr[fn];x;cons[cons[cadr[fn];
                                                    caddr[fn]];a]]]
    eval[e;a] = [atom[e] → cdr[assoc[e;a]];
        atom[car[e]] →
                [eq[car[e],QUOTE] → cadr[e];
                eq[car[e];COND] → evcon[cdr[e];a];
                T → apply[car[e];evlis[cdr[e];a];a]];
        T → apply[car[e];evlis[cdr[e];a];a]]
```

<u>pairlis</u> and <u>assoc</u> have been previously defined.

```
    evcon[c;a] = [eval[caar[c];a] → eval[cadar[c];a];
                T → evcon[cdr[c];a]]
and
    evlis[m;a] = [null[m] → NIL;
                T → cons[eval[car[m];a];evlis[cdr[m];a]]]
```

C **Recursion**

A recursive function is an operation that uses itself. Recursion enables programmers to break problems up into smaller, more easily solved problems, an approach called "divide and conquer." Recursive functions were useful in a lot of AI problems, as when a chess program tries a series of moves, evaluates the result, and then backtracks a couple of moves to try something different. Now, all programming languages (even Fortran) use recursion. In the highlighted text, the apply function is using the apply function.

"Lisp was a piece of theory that unexpectedly got turned into a programming language," wrote Paul Graham in his 2004 book *Hackers and Painters*. McCarthy's exploration of how to think about problems and how to create methods for solving them resulted in a computer language that has endured for five decades and changed the nature of computer programming. Church's Thesis—a central tenet of computation theory, named for the mathematician Alonzo Church—proposes that any possible calculation can, given enough time and computing power, be performed by a recursive function. Steele contends that "Lisp is the practical application of Church's Thesis."

SOURCE: THE LISP 1.5 PROGRAMMER'S MANUAL, BY JOHN MCCARTHY, P. 13 (MIT PRESS, 1962)

Bjarne Stroustrup

The problem with programming

In the 1980s and '90s, when he was a researcher at AT&T Bell Labs, the Danish-born computer scientist Bjarne Stroustrup designed C++, arguably the most influential programming language of the last 25 years. For all that, C++ is controversial. The language is widely disliked by the millions of programmers who use it, largely because it is notoriously difficult to learn and use, and because Stroustrup's design permits them to make serious programming mistakes in the interests of maximizing their freedom of expression. Today, Stroustrup is a professor of computer science at Texas A&M University.

***TR*: Why is most software so bad?**

Stroustrup: Some software is actually pretty good, by any standard. Think of the Mars Rovers, Google, and the Human Genome Project. Now, *that's* quality software! Our technological civilization depends on software, so if software had been as bad as its worst reputation, most of us would be dead by now.

On the other hand, the average piece of software code can make me cry. The programmers clearly didn't think deeply about correctness, algorithms, data structures, or maintainability. Most people don't know how bad it is because they don't read code: they just see Windows freeze or have their cell phone drop a call.

How can we fix the mess we are in?

We can't just stop the world for a decade while we reprogram everything from our coffee machines to our financial systems. On the other hand, muddling along is expensive, dangerous, and depressing. Significant improvements are needed, and they can only come gradually. But they must come on a broad front; no single change will be sufficient.

Looking at my own narrow field of programming-language design, my view is that a good language can be a major asset, but only when used appropriately and well. A language doesn't solve problems; it merely helps the expression of solutions.

What makes for a good programming language?

Anything that helps people express their ideas makes a language better. A language should be good at everyday tasks in the hands of good craftsmen. It matters less whether the language is beautiful in itself. There are more useful systems developed in languages deemed awful than in languages praised for being beautiful—many more.

Isn't elegance important?

Elegance is essential, but how do you measure elegance? The lowest number of characters to express the solution to a problem? I think we should look for elegance in the applications built, rather than in the languages themselves. It would be a stretch to call a carpenter's complicated set of tools (many quite dangerous) *elegant*. On the other hand, my dining-room table and chairs are elegant—beautiful, really. That said, it would of course be best if the language itself was a beautiful work of art.

Is C++ too hard for most programmers?

It shouldn't be. To use C++ well, you have to understand design and programming technique. In a sense, my critics are right: not everybody should write C++, but then I never claimed they should. C++ is designed to allow you to express ideas, but if you don't have ideas or don't have any clue about how to express them, C++ doesn't offer much help.

How do you account for the fact that C++ is widely criticized and resented by many programmers but is at the same time very broadly used?

The glib answer would be, There are just two kinds of languages: the ones everybody complains about and the ones nobody uses. The main reason for C++'s success is simply that it meets its limited design aims: it can express a huge range of ideas directly and efficiently.

In your book *The Design and Evolution of C++*, you claim that Kierkegaard was an influence upon your conception of the language. Is that a joke?

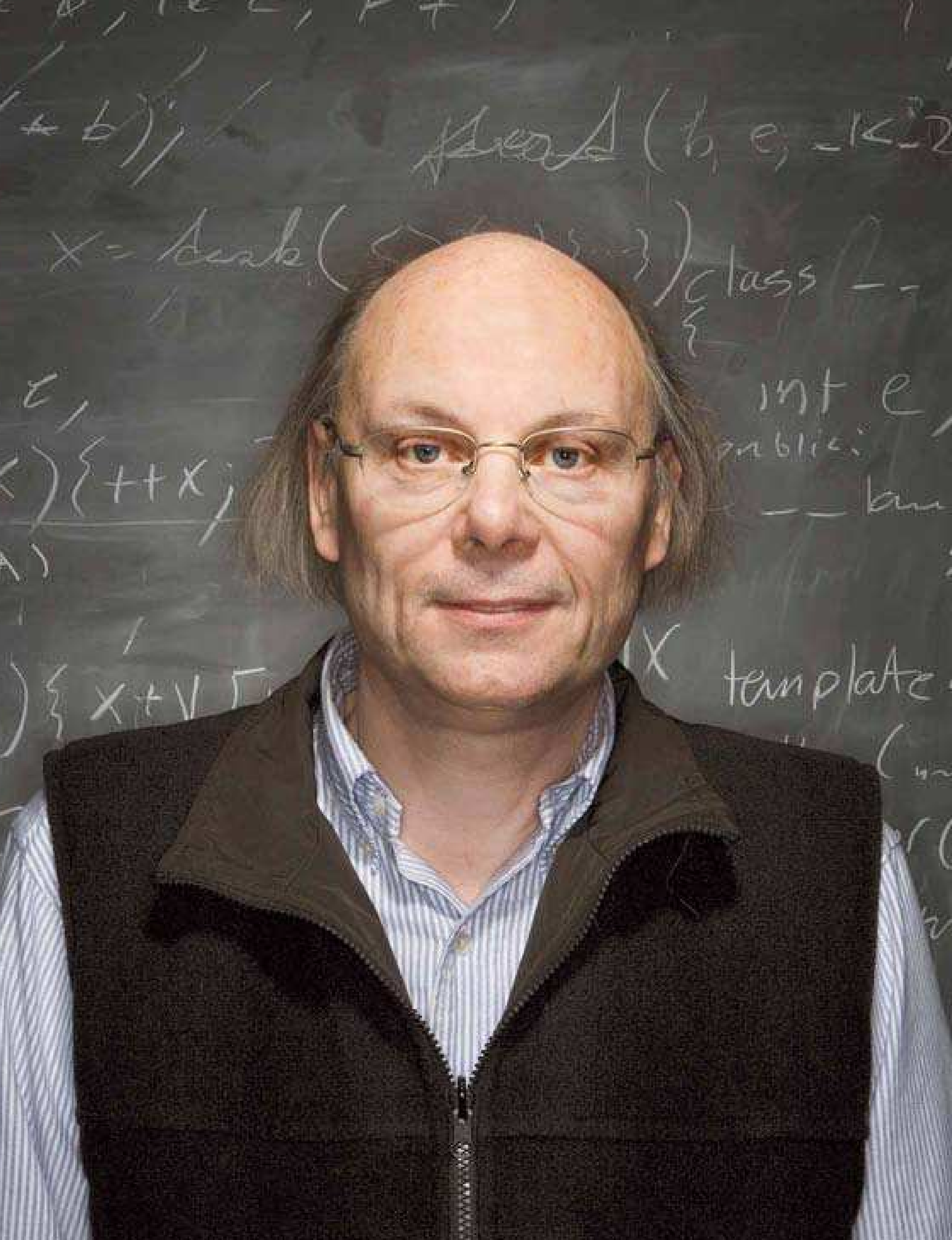
A bit pretentious, maybe, but not a joke. A lot of thinking about software development is focused on the group. Corporate practices can be directly hostile to individuals with exceptional skills and initiative. I consider such management of exceptional people both cruel and wasteful. Kierkegaard was a strong proponent of the individual against the crowd. I can't point to a specific feature of C++ and say, "See, there's the influence of the 19th-century philosopher," but he is one of the roots of my reluctance to eliminate expert-level features. I'm not particularly fond of his religious philosophy, though.

What do you regret the most?

No regrets! Well, of course I dream of what I might have done differently and better—but who am I to second-guess, say, 1984-vintage Bjarne? He may have been less experienced than I, but he was no less smart, probably smarter, and he had a better understanding of the world of 1984 than I have. C++ has been used to build many systems that enhance our lives, and it has been a significant positive influence on later languages and systems. That's something to be proud of.

JASON PONTIN

BRENT HUMPHREYS


class
template

ENERGY

China's Energy Dilemma

In a few years, China will be the world's largest emitter of carbon dioxide. Don't look for any quick and easy solution to the problem, says **Richard Lester**.

As evidence accumulates about the impact of fossil fuel use on the global climate, China's surge into the front ranks of the world's carbon emitters is an elephant in the room that we can no longer ignore. The numbers are sobering: the Chinese economy is growing by almost 10 percent annually, and its electricity demand by nearly 15 percent; roughly two big new coal-fired power plants are completed in China each week; new generating capacity equivalent to that of nearly the entire U.K. power grid was added last year alone; private car ownership is rising rapidly. In its latest projections, the International Energy Agency estimates that China will overtake the U.S. to become the world's largest carbon emitter within five years *(see "China's Coal Future," p. 56)*.

Some invoke such data to argue that it is pointless for the United States to curtail its carbon emissions unless the Chinese begin to reduce theirs, which they show no sign of doing. Others say that argument is disingenuous—a convenient excuse to avoid painful choices at home—and that attempts to pressure China (and other developing countries) to reduce carbon emissions will simply be ignored if we fail to get our own house in order.

The truth is that the United States and China—between them responsible for 40 percent of global carbon emissions—have many good reasons to collaborate on emission reductions. But as U.S. policymakers consider their options for engaging the Chinese, they should keep two points in mind.

First, as relations with China move toward the center of U.S. foreign-policy concerns in the coming years, the global-warming problem—serious as it is—will be just one of several issues in which the U.S. has a major interest. Others include trade investment and industrial competition; the North Korean nuclear crisis and security in Northeast Asia; the developing contest for power and influence in energy-rich central Asia, the Middle East, and Africa; Chinese nuclear technology exports; and the longer-run prospect of China's emergence as a global superpower and geostrategic rival. America's interest in reducing China's carbon emissions will not always be aligned with its other objectives. (Consider, for example, that a successful effort to slow the growth of China's huge domestic coal industry will inevitably increase its already voracious appetite for oil and gas from the Middle East and elsewhere.) Managing this complex policy agenda will require not single-issue zealotry but, rather, hard choices among competing priorities, disciplined execution, and sustained statesmanship.

Second, notwithstanding growing environmental awareness in China, Beijing's ability to act on the global-warming issue will be limited. This is not only because the legitimacy of the central government rests on its ability to continue delivering rapid economic growth, so that any perceived threat to that growth will meet with resistance. It is also because the fragmented, decentralized system of energy-related governance in China will hamper the government's ability to meet any carbon mitigation commitments it does make. The fact that the Chinese state is authoritarian does not mean that it is internally coherent or effectively coördinated. China's energy system is in its own way as politically complex, fractured, and unwieldy as our own. And we would be unwise to expect of the Chinese what we are unable or unwilling to ask of ourselves. TR

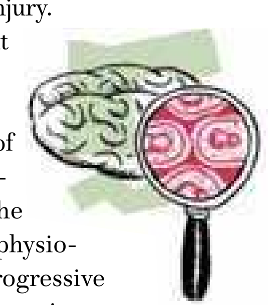
Richard Lester, an expert on energy technology and policy, is a professor of nuclear science and engineering at MIT and the founding director of its Industrial Performance Center.

MEDICINE

The Brain Injury Epidemic

There are still no treatments for traumatic brain injury, though **Barclay Morrison** offers cause for hope.

Every year traumatic brain injury (TBI) causes 50,000 deaths and 80,000 cases of long-term disability in the United States, according to the Centers for Disease Control and Prevention. An estimated 5.3 million Americans (some 2 percent of the population) live with long-term disabilities due to brain injury.



Yet much about brain injuries remains unknown. Despite decades of research, no treatments yet target the underlying pathophysiological cause of progressive brain damage. For patients so severely injured that they are in a minimally conscious state, medical knowledge is particularly lacking; in such cases, we are just beginning to understand the damage and the possibility of treatment *(see "Raising Consciousness," p. 50)*.

ILLUSTRATIONS BY MARC ROSENTHAL

Preventing brain injuries is enormously important. Prevention strategies include such commonsense devices as air bags in cars, protective helmets, and cushioned playground materials. Detailed knowledge of TBI biomechanics at both the whole-body and single-cell levels can make prevention even more successful. Equipped with this information, computational models can predict how likely an event is to cause injury and how effective a protective device is likely to be.

Finding treatments for those injuries that do occur will depend on better understanding the complex cellular events triggered by a brain injury. In TBI, a rapid mechanical deformation of the brain both physically disrupts and mechanically stimulates cells. Some cell damage is immediate, but most of the damage develops over days, weeks, and even months. The delayed and progressive nature of the neurodegenerative cascade represents a critical therapeutic opportunity: targeted intervention could halt the progression of cell damage and death. However, no therapeutic strategies yet exist that target the degeneration mechanisms.

One approach, which my research group is working on, is to develop experimental TBI models that simulate the neurodegenerative sequence. With the molecular understanding that such models offer, promising therapeutic targets can be identified and treatments rationally developed with the intent of breaking the progression from mechanical event to delayed cell death. Boosting the brain's own protective mechanisms is another possible tactic. Finally, therapeutic strategies to encourage sprouting of new brain tissue or regeneration of damaged tissue could also hold promise for those living with long-term disability.

Our understanding of TBI is greater today than it has ever been. But TBI must continue to be studied so that effective treatments can be found for the approximately 230,000 people each year who suffer head injuries that require hospitalization. TR

Barclay Morrison is an assistant professor of biomedical engineering at Columbia University and the principal investigator in its Neurotrauma and Repair Laboratory.

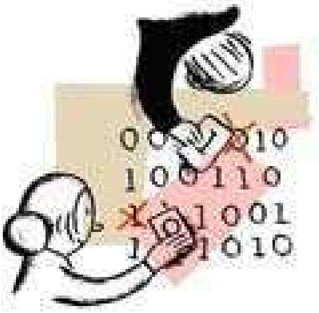
INFORMATION TECHNOLOGY

The Open-Source Solution

Larry Constantine asks, If most commercial software isn't any good, why not use a more communal approach?

As you read this, countless programmers worldwide are collaborating to write, refine, and debug open-source software. Open-source pioneer Richard Stallman estimates that a million programmers now contribute to these efforts, in which the original written form of the code—the source—is made freely available for everyone to work on and worry over. Once a fringe phenomenon, the practice has grown into a major force in software development.

Open source is both a movement and a method. Partisan passions rage, but politics and polemics aside, the open strategy for constructing and maintaining programs may offer some distinct advantages over the closed-door development practices that dominate commercial software.

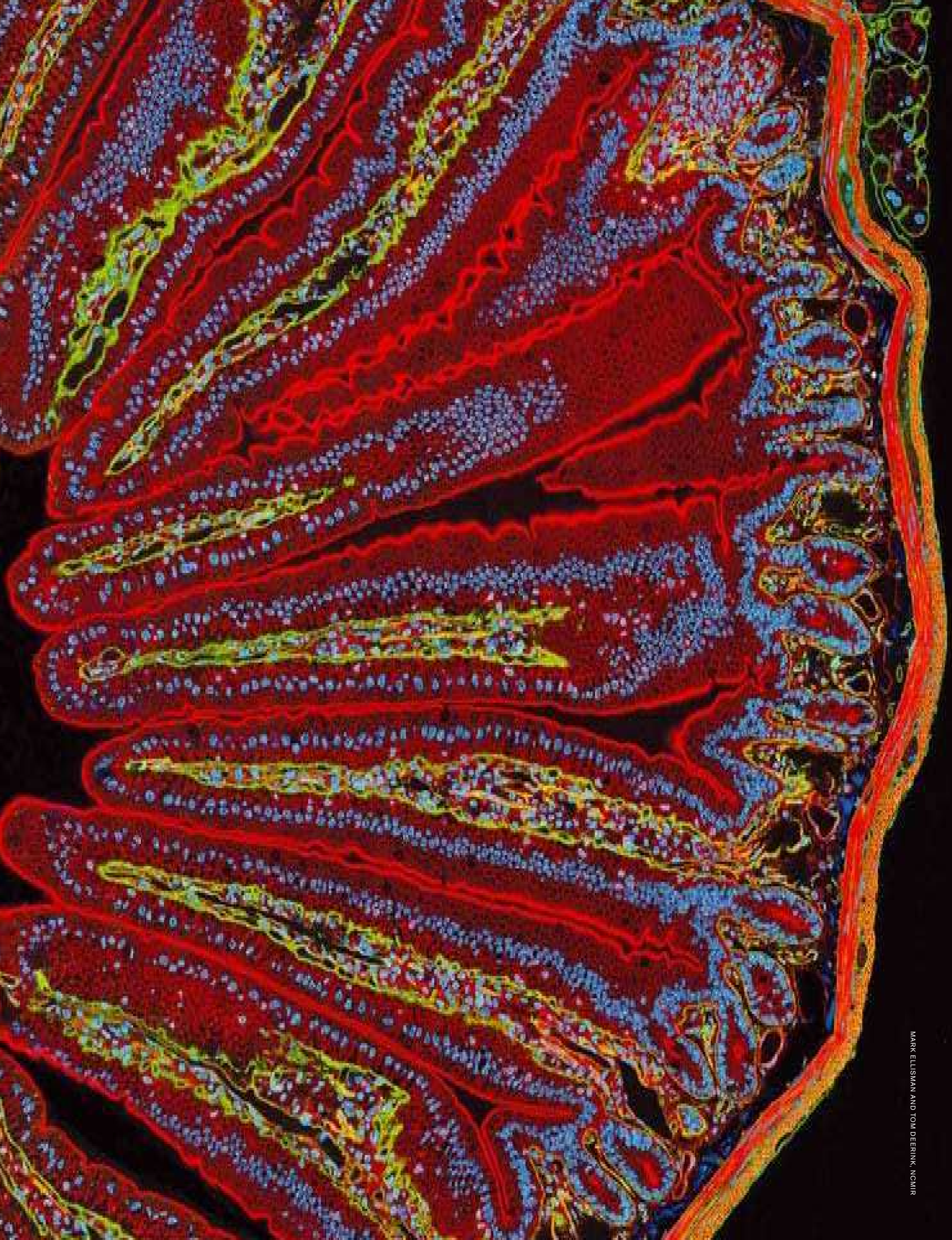


The most common argument for open-source development, and perhaps its greatest strength, is the sheer number of people who address a given problem. Every line of code, and its relationship to many others, is scrutinized again and again in an almost obsessive-compulsive competition to be the first to find a problem or its solution. In principle, and often in practice, this transparency can generate cleaner, more economical code with fewer bugs or vulnerabilities (for a discussion of the problems with mainstream software, see "Anything You Can Do, I Can Do Meta," p. 36). There are, of course, no guarantees, but the reliability record of open-source software is excellent.

Collaboration can cut both ways, however. Because new functions may be proposed and appended by almost anyone at any time, open-source software can become every bit as feature-rich as its commercial cousins, and thus equally vulnerable to the creeping excess that bedevils many mainstream products. As the code slowly grows in complexity as well as capability, usability suffers, not only because new functions add to the user interface but because such additions are ad hoc and implemented case by case.

Open source may be superior in producing robust, reliable code. It can hold its own in providing functionality. But its weakness remains usability, which increasingly is the battleground for competing programs. Finally, though, initiatives like the GNOME free desktop software for Unix have been closing the usability gap between open-source and commercial software. While open source may not solve the problem of bad software, it does offer many innovative possibilities. Most important, it demonstrates that when more people scrutinize code more closely, the effort can pay off in reliability. The jury is still out on usability. TR

Larry Constantine teaches and heads a software R&D lab at the University of Madeira, Portugal. He is also a usability expert and software design consultant.



MARK ELLISMAN AND TOM DEERINK, NCMIR

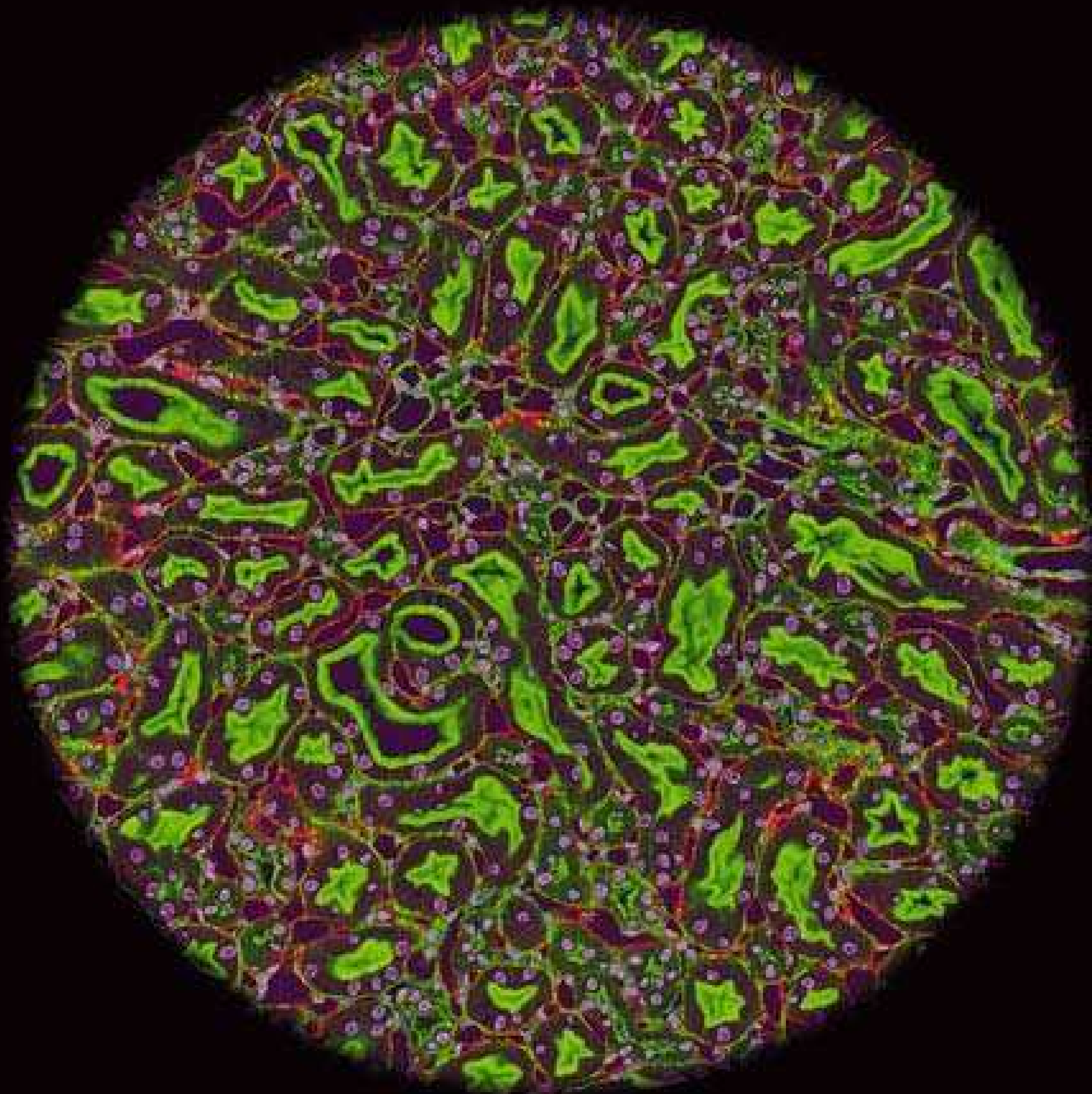


Photo Essay

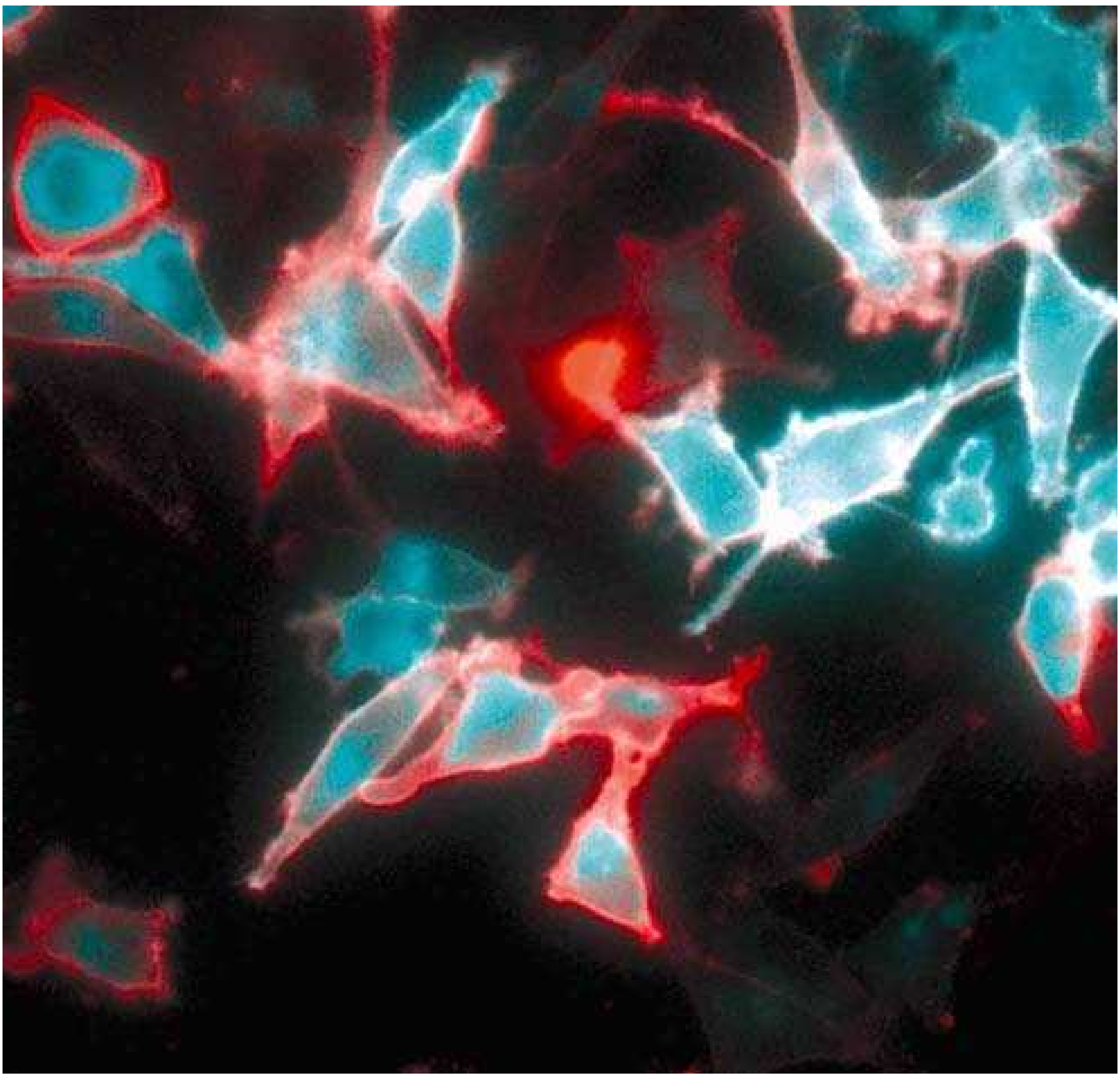
Peering into Cellular Worlds

The ability to tag individual proteins with fluorescent labels has revolutionized the world of molecular biology by allowing scientists to peer into cells. New twists on fluorescence imaging—described in the following pages—allow them to look closer than ever before. **By Emily Singer**

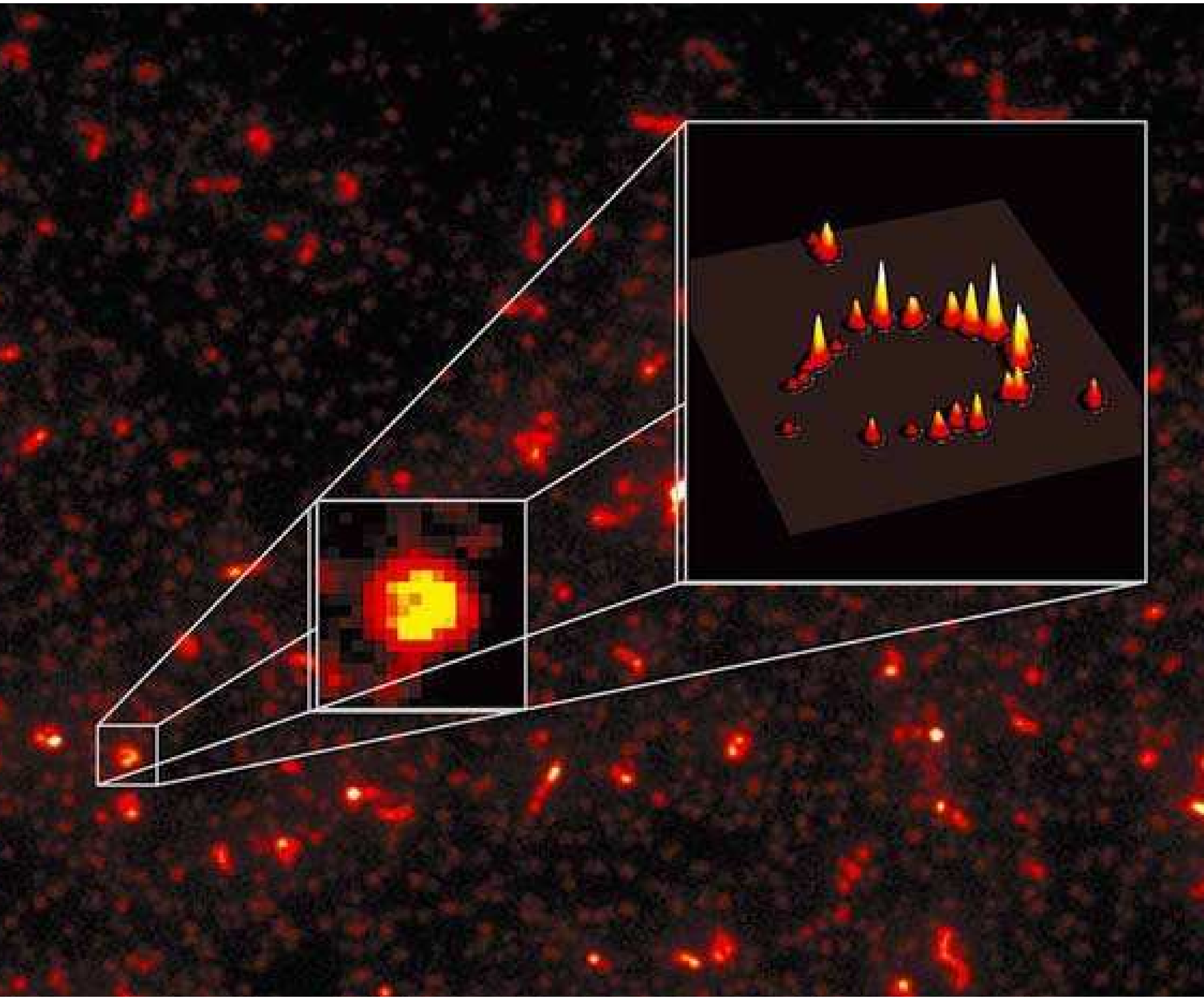
Fluorescent tags have been designed for a myriad of proteins. But many of the current tags have problems: they fade easily, or they don't come in enough colors to study many different proteins at once. A new type of fluorescent tag, made up of nanometer-size crystals known as quantum dots, could solve those problems. Scientists can create quantum dots in a rainbow of colors. And because quantum dots of all colors can be excited by the same wavelength of light, scientists can use them to examine a multitude of protein molecules simultaneously.

On the preceding pages, a mouse small intestine (left) and mouse kidney (right) are labeled with red and green quantum dots that target two types of proteins, and with a dye that stains cell nuclei blue.

Fluorescent labels are typically attached to proteins with bulky antibodies that may inhibit the proteins' normal behavior and can form unstable bonds. But a new method for attaching labels, developed by Alice Ting, assistant professor of chemistry at MIT, uses smaller linkers that attach the label more tightly. Ting and her colleagues first genetically modify the protein of interest with a special tag. Then they prepare fluorescent labels with another tag and add an enzyme that binds the tags together. The resulting linker is extremely stable and allows researchers to track the movement of individual proteins within a cell over long periods of time. The image below shows cells genetically engineered to express a protein that causes them to glow blue. The blue protein has been tagged along the perimeter of each cell with a red fluorescent label.



ALICE TING, MIT

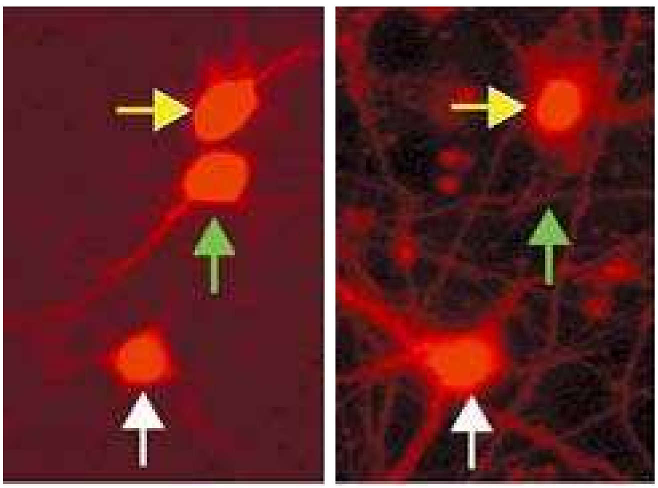


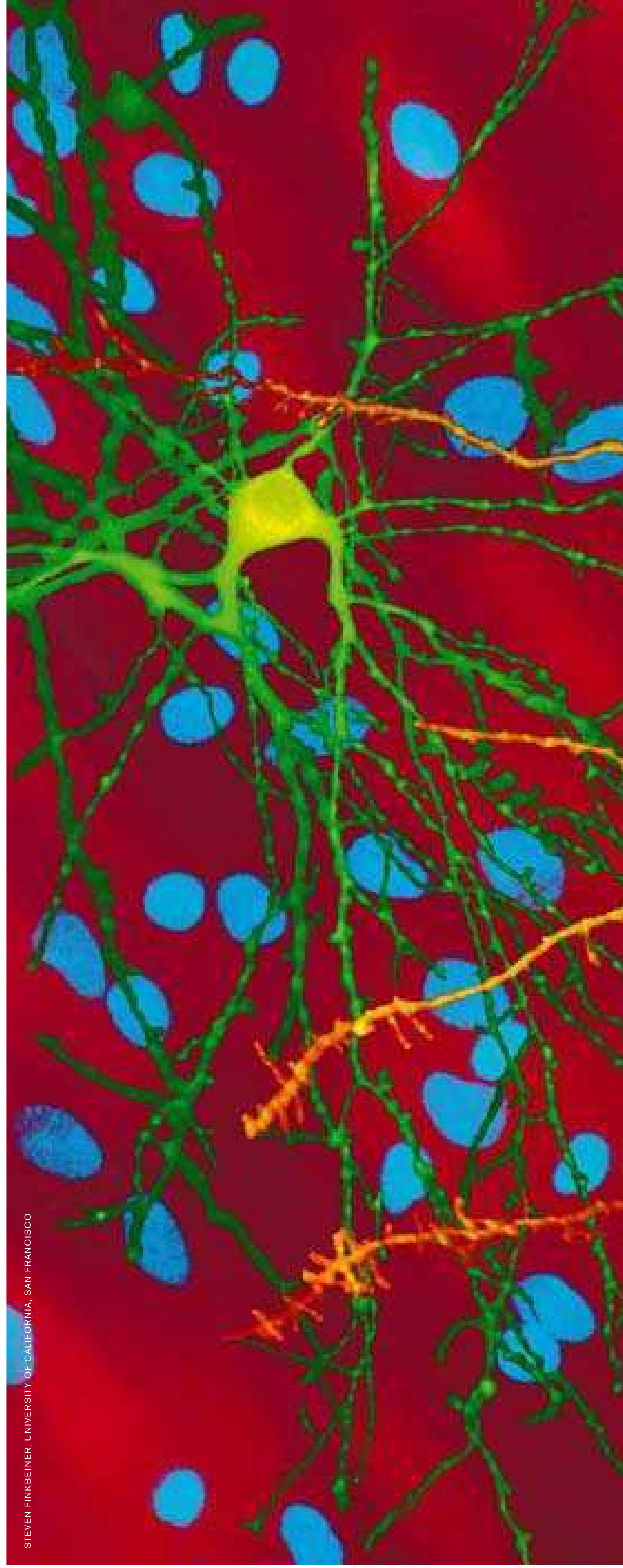
XIAOWEI ZHUANG, HARVARD

Although the two methods described here so far provide a way to look at molecules inside cells, they can't image anything smaller than about 300 nanometers. The ability to distinguish, say, a pair of five-nanometer proteins would open a new window onto the inner workings of cells, says Xiaowei Zhuang of Harvard University. Zhuang labels proteins with specially designed fluorescent tags that can be quickly turned on and off with light. She then activates only a few sparsely placed tags at a time. These are clearly separate from each other under an optical microscope, allowing her to map their precise locations. The process is repeated again and again, each time capturing the location of a few tags. Then the images are combined to create a cohesive picture. "Having such a high-resolution technique allows interactions among molecules to be much better revealed in a cell," says Zhuang.

In the image above, a circular filament made of DNA-binding proteins is shown as depicted both by conventional wide-field microscopy—a yellowish blob—and by Zhuang's technique, which reveals a crisp ring of peaks, indicating the location of tag molecules.

Photo Essay





STEVEN FINKBEINER, UNIVERSITY OF CALIFORNIA, SAN FRANCISCO

Traditional cell-imaging systems typically take snapshots of cells at fixed points in time. But an automated microscope developed by Steve Finkbeiner at the Gladstone Institute of Neurological Disease at the University of California, San Francisco, may help change that. Over a period of hours to days, the microscope takes a series of pictures of cells growing on a plate. Specially designed software identifies the cells of interest, which are labeled with a fluorescent tag, and tracks how those cells change.

In the image at right, a neuron from a rat with genetic mutations similar to those that cause Huntington's disease in humans is shown in yellow, with a protein cluster shown in red. The blue circles are the nuclei of glial cells, a type of support cell in the brain. The photos above, taken from a series collected over a span of 60 hours, show a cell death (marked by a green arrow).

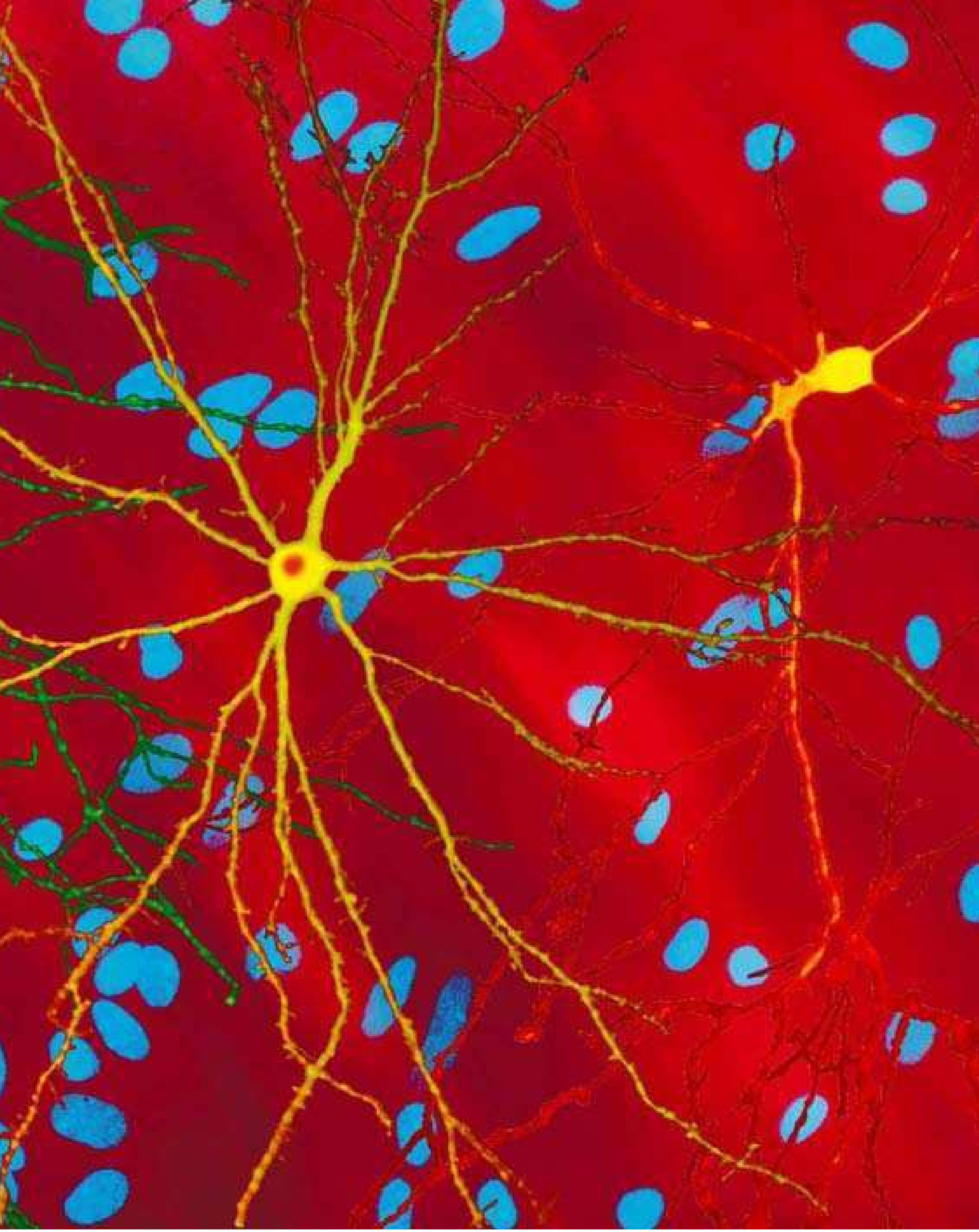
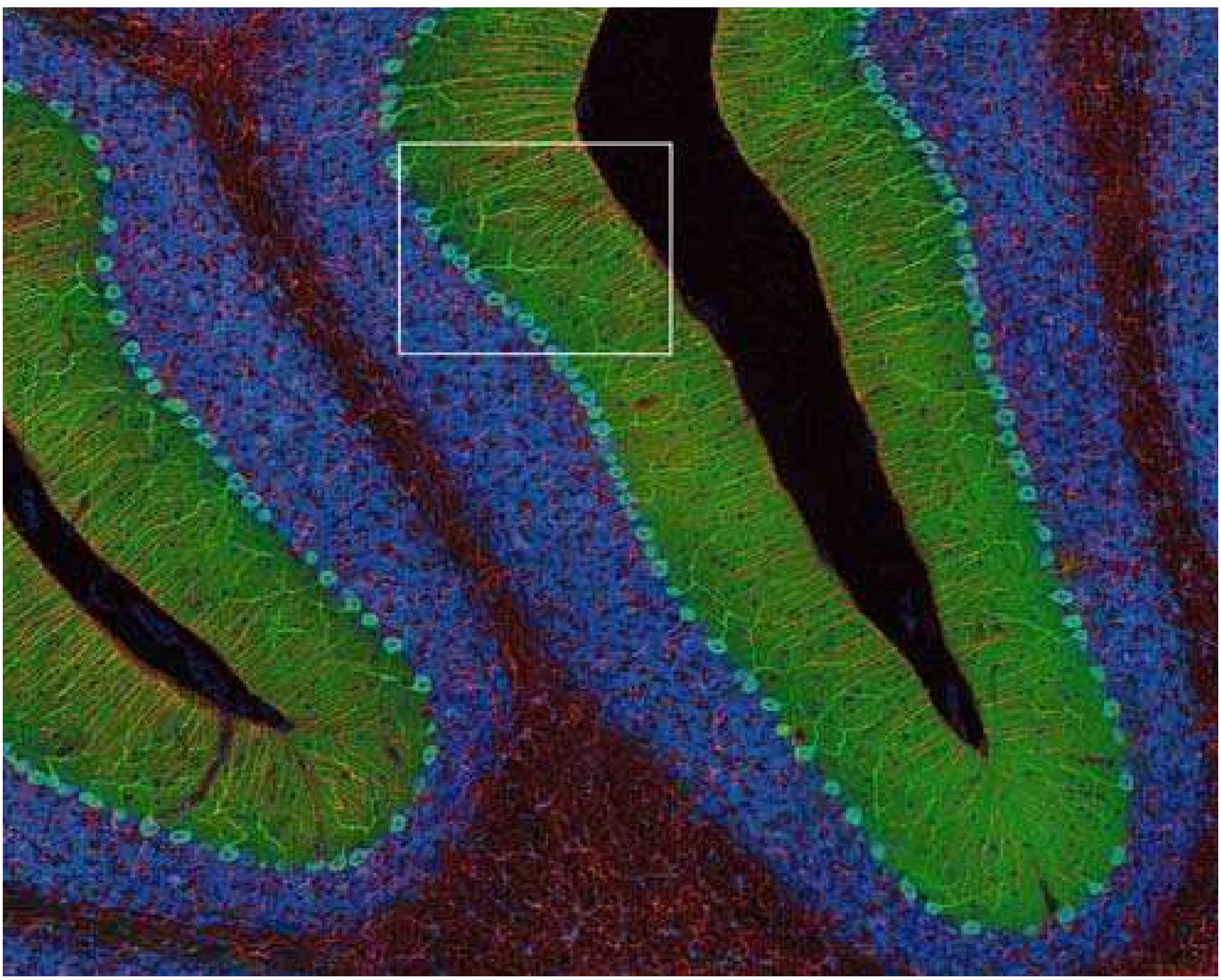


Photo Essay

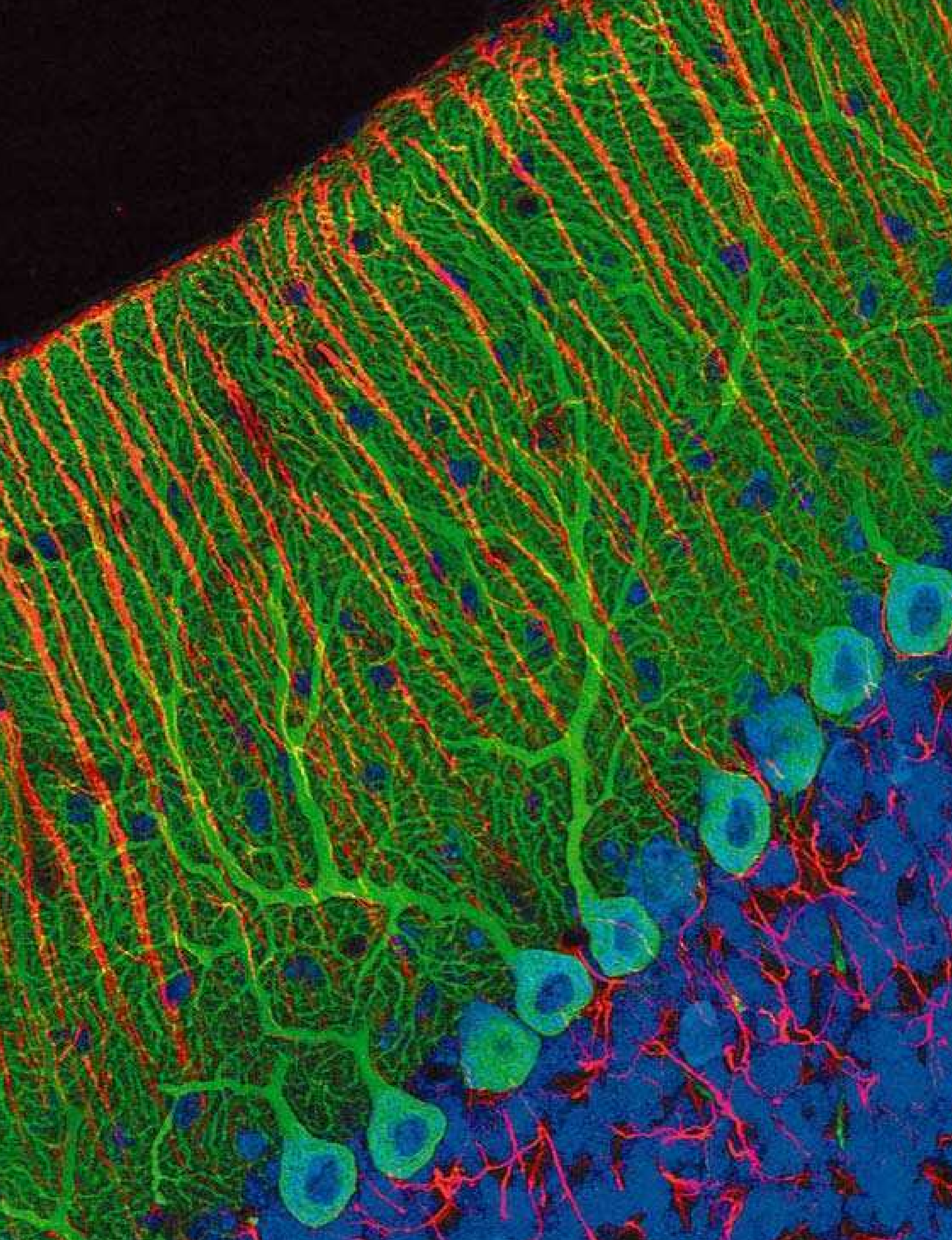
Extremely subtle variations in brain structure may lie at the root of schizophrenia, autism, and disorders of the nervous system. To find these elusive flaws, scientists must be able to study the brain at very high resolutions over large areas and in three dimensions. But most high-resolution imaging techniques can look only at limited areas of brain tissue.

Recent developments in computer-aided microscopy promise to overcome these limitations. In a method developed by Mark Ellisman's group at the National Center for Microscopy and Imaging Research (NCMIR) at the University of California, San Diego, a microscope takes a series of 3-D pictures of a slice of tissue, which is moved slightly between pictures by a motorized, high-precision microscope stage. Software then combines the images into a single, seamless composite.

At left, a cross section of a rat cerebellum has been stained with three types of fluorescent dyes, to highlight both individual brain cells and the layered organization of the tissue. Below and right, the image is shown at higher magnifications. The image, which is composed of 43,500 separate snapshots, took more than 20 hours to acquire and occupies several gigabytes of disc storage space.



MARK ELLISMAN AND TOM DEERINK, NCMIR



Anything You Can Do, I Can Do Meta

Space tourist and billionaire programmer Charles Simonyi designed Microsoft Office. Now he wants to reprogram software.

By Scott Rosenberg

On April 9, at a remote launchpad on the plains of Kazakhstan, a ground controller will finish his countdown; a Soyuz rocket will fire; and Charles Simonyi—Microsoft's former chief architect, the tutelary genius behind its most famous applications, the inventor of the method of writing code that the company's programmers have used for 25 years, and now the proponent of an ambitious project to reprogram software—will begin his ascent into space.

Snug in a Russian space suit, feeling four Gs pressing him down into a form-fitting molded seat liner, the 58-year-old billionaire will become the fifth space tourist to visit the International Space Station. The journey, which will cost Simonyi around $20 million, will fulfill his dream of becoming a "nerd in space" (to borrow one name he chose for the website that documents his extraterrestrial adventure: www.nerdinspace.com). It will also give him an opportunity to view our planet from above and beyond.

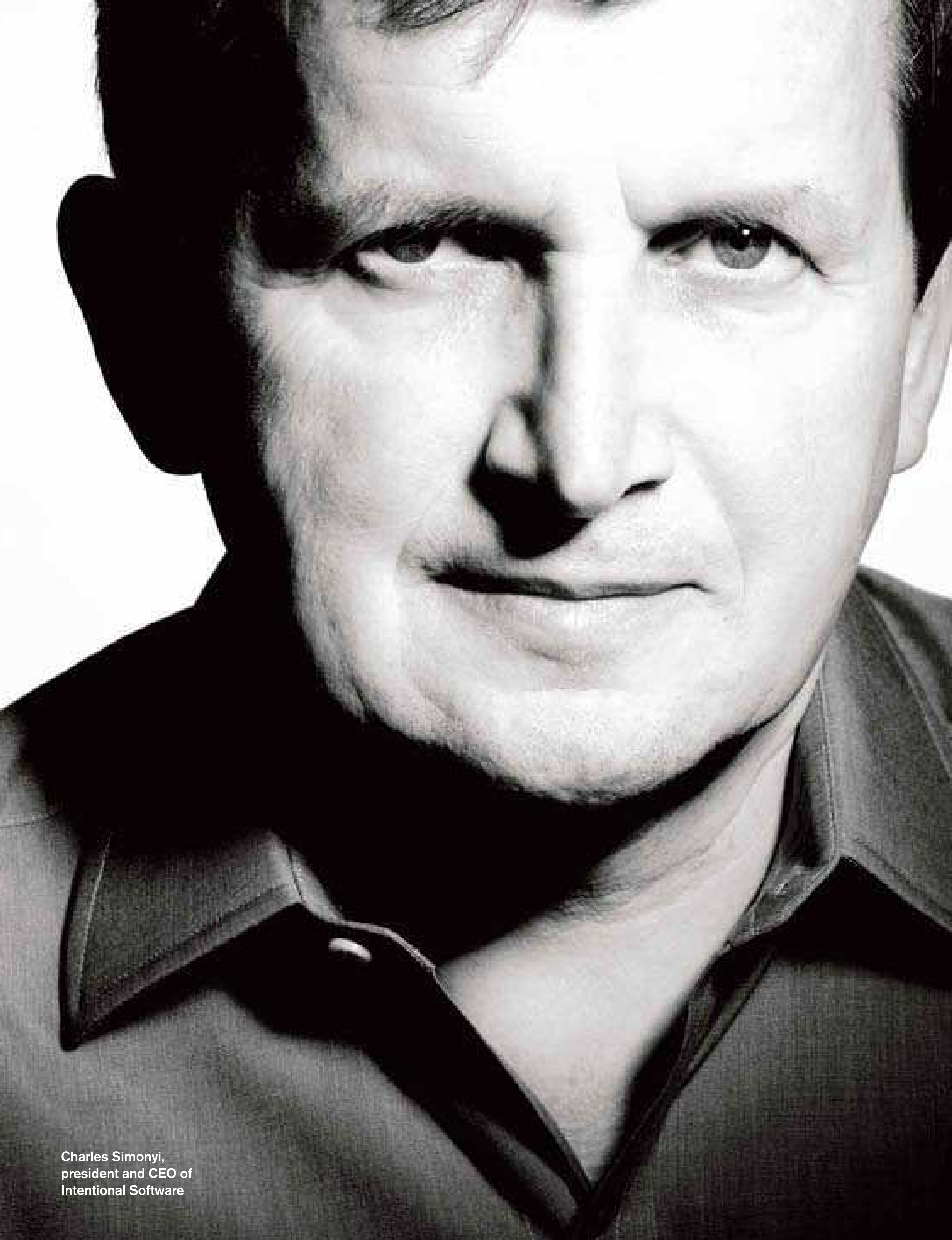
This has always been Simonyi's preferred vantage. In a career spanning four decades, every time he has confronted some intractable problem in software or life, he has tried to solve it by stepping outside or above it. He even has a name for his favorite gambit: he calls it "going meta." In his youth in 1960s Hungary, he learned the basics of computing on an antiquated Soviet mainframe powered by vacuum tubes, then engineered his own escape to the West. In the 1970s, at Xerox's legendary Palo Alto Research Center (PARC), as part of the team that invented personal computing, Simonyi wrote the first modern application: a word processor that banished the complex codes then used to tag text and displayed a document as it would look on paper. Whether in his Stanford University doctoral dissertation on a "metaprogramming" approach to boosting programmer productivity, his career at Microsoft organizing legions of software developers and teaching them how to structure their code, or his planned voyage into Earth orbit this spring, moving beyond established ways of doing things has always been Simonyi's method. Now he is plotting what he hopes will be his most vaulting meta-move of all. Simonyi believes he can solve a host of stubborn problems that have always plagued computers by offering everyone who uses them, and the coders who program them, a higher-order view of software.

Bill Gates calls Simonyi "one of the great programmers of all time." Indeed, Simonyi is arguably the *most* successful coder in the world, measured in terms of financial reward and the number of people who use his creations. (Other celebrated programmer-billionaires, such as Larry Ellison and Bill Gates himself, made their money and names founding and managing technology ventures.) Simonyi could easily choose to spend the rest of his life endowing philanthropic ventures, flying planes, or cruising in his yacht. Instead, he says, he is "programming probably harder than ever before." He is obsessed with a project that he has pursued for a decade and a half, and that four years ago carried him right out of Microsoft's doors. He is proud of his profession. But he is also haunted by the thought of what programmers must contend with each time they sit down to code. He asks, Why is it so hard to create good software?

Napoleonic Code

"Our civilization runs on software," says Bjarne Stroustrup, the inventor of the C++ programming language *(see "The Problem with Programming," p. 22)*. But the software itself doesn't run very well. Everywhere you look, software is over budget, behind schedule, insecure, unreliable, and hard to use. Anytime an organization attempts to introduce a new system, or upgrade an old one, it takes a colossal risk; today, large information-technology projects are technological tar pits that immobilize institutions. Studies regularly report that two-thirds of such projects encounter major delays, sig-

BRIAN SMALE



Charles Simonyi,
president and CEO of
Intentional Software

nificant cost overruns, or both. The U.S. government has found it nearly impossible to introduce or upgrade large-scale software systems: decade-long efforts at the Federal Aviation Administration and the FBI have collapsed in chaos. Businesses have fared no better. To give a single example, McDonald's executives dreamed of a Web-based management system they called Innovate that would track the real-time flow of burgers, fries, and chicken nuggets in every one of their restaurants around the world. By the time they gave up and canceled the project, they had to write off $170 million of its estimated $1 billion total cost.

Such failures add up. Every year, according to a 2002 study by the National Institute of Standards and Technology, software failures cost $59.5 billion. But the price of bad software can also be measured in human misery—and even in lives lost. During the 1991 Gulf War, a Patriot missile battery didn't fire at an incoming Scud because of faulty software; the direct hit on a barracks killed 28 U.S. soldiers.

The past half-century of computing has seen wonderful progress. Programmers have abandoned punch cards and teletypes. They have given us a computer on every desktop, tools for work, toys for play, and a network that links homes and businesses to form a teeming global pool of information and entertainment. This progress has been fueled by the exponential curve of Moore's Law, Intel founder Gordon Moore's prediction that microchips' power would double (or their cost would halve) every one to two years. But even as Moore's Law has made each year's new computers faster and cheaper, the flexibility and utility of our computer systems have been limited by the slower, uneven evolution of software. One formulation of this problem is known as Wirth's Law, after programming expert Niklaus Wirth: "Software gets slower faster than hardware gets faster."

Simonyi shares much of the common dissatisfaction with software. "Software as we know it is the bottleneck on the digital horn of plenty," he says. "It takes up tremendous resources in talent and time. It's disappointing and hard to change. It blocks innovation in many organizations."

Simonyi's ambition is to unstop that software bottleneck—characteristically, by going meta. He's developed an approach he calls intentional programming (or, more recently, intentional software), which he hopes will overturn programming. If Simonyi has his way, programmers will stop trying to manage their clients' needs. Instead, for every problem they're asked to tackle—whether inventory tracking or missile guidance—they will create generic tools that the computer users themselves can modify to guide the software's future evolution.

On a gray afternoon last October, I sat down with Simonyi in Bellevue, WA, in front of two adjacent screens in his office at Intentional Software, the company that he founded after he left Microsoft in 2002 to develop and commercialize his big idea. Simonyi was racing me through a presentation he was preparing for an upcoming conference; he used Microsoft Office PowerPoint slides to outline his vision for the proposed great leap forward in programming. He was in the middle of moving one slide around when the application just stopped responding.

In the corner of the left-hand screen, a goggle-eyed paper clip popped up: the widely reviled "Office Assistant" that Microsoft introduced in 1997. Simonyi tried to ignore the cartoon aide's antic fidgeting, but he was stymied. "Nothing is working," he sighed. "That's because Clippy is giving me some help."

I was puzzled. "You mean you haven't turned Clippy off?" Long ago, I'd hunted through Office's menus and checked whichever box was required to throttle the annoying anthropomorph once and for all.

I was puzzled. "You mean you haven't turned Clippy off?" Long ago, I'd hunted through Office's menus and checked whichever box was required to throttle the annoying anthropomorph once and for all. "I don't know how," Simonyi admitted.

"I don't know how," Simonyi admitted, with a little laugh that seemed to say, *Yes, I know, isn't it ironic?*

It was. Simonyi spent years leading the applications teams at Microsoft, the developers of Word and Excel, whose products are used every day by tens of millions of people. He is widely regarded as the father of Microsoft Word. (I am, of course, using Word to write these sentences.) Could Charles Simonyi have met his match in Clippy?

Simonyi stared at his adversary, as if locked in telepathic combat. Then he turned to me, blue eyes shining. "I need a helper: a Super-Clippy to show me where to turn him off!" Simonyi was hankering for a meta-Clippy.

In 2004, Simonyi proposed his own law: "Anything that can be done could be done 'meta.'" In his younger days—when he'd grandiosely named a project "Simonyi's Infinitely Glorious Network"—he would probably have been more arrogant: "Anything you can do, I can do meta!" But like many prodigies who have done well and aged well, Simonyi has learned to cut his cockiness with touches of humility and grace. A decade ago, he described himself as "a

CELEBRITY PROGRAMMER **Simonyi (left) in 1990, with his Microsoft team, on Bill Gates's lawn and (right) with Martha Stewart and Sophia Loren at a Russian National Orchestra gala last year**

GEORGE C. STEINMETZ/CORBIS (LAWN); STEPHEN CHERNIN/ASSOCIATED PRESS (GALA)

shaggy-looking guy with a foreign accent." He favors black turtlenecks and double-breasted blazers. With his upright posture and square face, a shock of dark hair combed forward over his forehead, he is often said to resemble a larger-boned Napoleon.

Intentional software is a grand scheme in a field where grand schemes have seldom worked. Every previous innovation introduced as a complete solution to software's woes has ended up providing no more than modest, incremental improvements. But Simonyi brims with the confidence of a self-made immigrant who's always had a firm grip on his own bootstraps. In a photo that hangs over his desk, he is standing in the White House beneath a portrait of Ronald Reagan. His broad grin mirrors the president's. The caption reads "The Two Optimists."

The offices of Simonyi's new company occupy a suite in a sleek glass skyscraper, and if you lean into the window and look down you can see the roof of the squat, nondescript white building that housed his first office at Microsoft, back in 1981. (It's a bank now.) Since then, Microsoft has grown beyond all recognition. The software industry has transformed the world. So why would Simonyi set out to rewrite all its rules? The problem is so big it seems part of the settled order of things. Simonyi's proposed solution could take decades to complete, and his critics are intensely skeptical. No one is asking him to leave behind the known routines of programming and strike off for a new world. But such migrations have paid off for him in the past.

The Machine's Language

Simonyi was born in Budapest in 1948. The son of a physics professor, he fell in love at 15 with his first computer—a mammoth Russian Ural II in Hungary's Central Statistical Office. By the 1960s, the Ural, which received its instructions through cash-register-style keys and had a roomful of vacuum tubes to perform calculations, would already have been a relic anywhere else in the world. But Hungary's Communist leaders were trying to use the Soviet castoff to optimize rail and trucking schedules. The Ural wasn't up to the task: there was no way to input real-time data on shipments. "It was completely hopeless," Simonyi recalls. "It could have been done very easily by supply and demand. Unfortunately, that was politically incorrect."

But Simonyi didn't care. "I loved that computer," he says, "even though it was useless." As a child he had built an Erector Set car with a four-speed transmission—not so much because he wanted to play with it as simply to understand how it worked. A former student of his father's found Simonyi a job as the Ural's night nurse. Because the machine blew out a tube each time it was turned off and on, the Statistics Office preferred to allow it to run all night. Thus, from dusk to dawn, the mainframe was all Simonyi's; he had a personal computer before such things existed. He learned to program it by writing clever but useless routines to generate "magic squares"—numerical arrays in which the sums of the rows, columns, and diagonals all match.

Programmers elsewhere in the world had already invented a Babel of programming languages—Fortran, Cobol, Lisp (a fabled language: see "Ancient Text," p. 20), and so on—to ease their work, which then as now consisted of painstakingly writing elaborate sets of instructions for computers to execute. In those languages, the instructions took the form of lines of text that were entered on keyboards and frequently stored on punch cards. This "source code" was then "compiled," or translated into "machine code"—the *1*s and *0*s that a digital computer could understand. The method remains largely unchanged today, even if most programmers now use programming tools running on ordinary PCs. But on the Ural, Simonyi learned to program at a more primitive level, laboriously punching in the "opcodes" of machine language, specifying, instruction by instruction, the sequences of memory fetches, additions, memory stores, and jumps that the computer's processor had to follow to execute even the most trivial operation. It was (as Simonyi told author Steve Lohr in the 2001 book *Go To*) "Stone Age programming." Simonyi still remembers the codes. "Twenty-two is JUMP," he says today. "It's burned into my ROM."

Hungary in the 1960s, still flinching from the Soviet suppression of its 1956 revolt, was not a place for an ambitious

young man with a taste for problem-solving. At 17, Simonyi landed an internship with a Danish computer company by showing some of its programmers samples of his hand-coded Ural programs. The Hungarian authorities expected Simonyi to return; he'd already won a coveted university spot. Instead, with his father's encouragement, he fled to the United States.

A letter of recommendation from Danish programming expert Peter Naur helped him win entry to the University of California, Berkeley. He paid the bills with a job at Berkeley's computer center, where he caught the attention of a faculty member named Butler Lampson. Lampson was one of the leaders of the U.S. Defense Advanced Research Projects Agency's Project Genie—an experiment in time-sharing computer systems, in which multiple users sitting at terminals could share a single computer's brain time. When the Project Genie creators started a company, called the Berkeley Computer Corporation (BCC), whose purpose was to build a machine that would commercialize their work, Lampson recruited Simonyi.

At BCC, Simonyi would debug the company's balky prototype through the night, working with system designer Chuck Thacker. One night, Simonyi showed up in a see-through black outfit—"a kind of a hippie thing from one of the shops on Telegraph Avenue," he says. Today, he can't remember exactly why—coming from a party, perhaps? The debugging went especially well that night, and the outfit became a good-luck charm—Simonyi's "debugging suit."

BCC went belly-up after only a few years, but Lampson, Thacker, and much of the BCC team migrated to Xerox PARC. Simonyi—then just "a random Hungarian undergraduate without a green card," as he says now—joined them in 1972, laboring at Xerox while simultaneously pursuing his Stanford doctorate. Bob Taylor, who oversaw PARC's Computer Science Lab during part of that legendary era, says Simonyi's creativity stood out even in the lab's famous crowd: "He just could imagine ways of expressing code and ideas that put him off the charts."

It was a heady time. The team of visionary engineers was creating a series of innovations that would shape the next quarter-century of the PC era: the graphical user interface, networking (Ethernet), the laser printer, object-oriented programming (Smalltalk), portable computing (the Dynabook), and more. These breakthroughs all converged on a prototypical personal computer called the Alto.

The Alto was an amazing invention, but it wasn't clear what you could do with it until Simonyi and his colleagues created its best-known application: a word processor called Bravo, whose on-screen display of type matched what the system would output to the new laser printer. Existing word processors had elaborate systems of codes for formatting text on the screen (anyone who used WordPerfect on a PC in the 1980s will remember its "embedded codes"); Bravo let you forget about the codes, directly manipulate the design of a document, and immediately witness the changes. A visiting Citibank executive looked at a demo and quoted a signature line of comedian Flip Wilson's sassy character Geraldine: "What you see is what you get!" The name (reduced to the acronym Wysiwyg and pronounced *wizzywig*) stuck. Suddenly, Bravo had users: relatives and friends of PARC researchers began asking to use it to print school newsletters and format academic papers. Lampson's wife printed her thesis using the system, and when it was time for Simonyi to print his, he did the same.

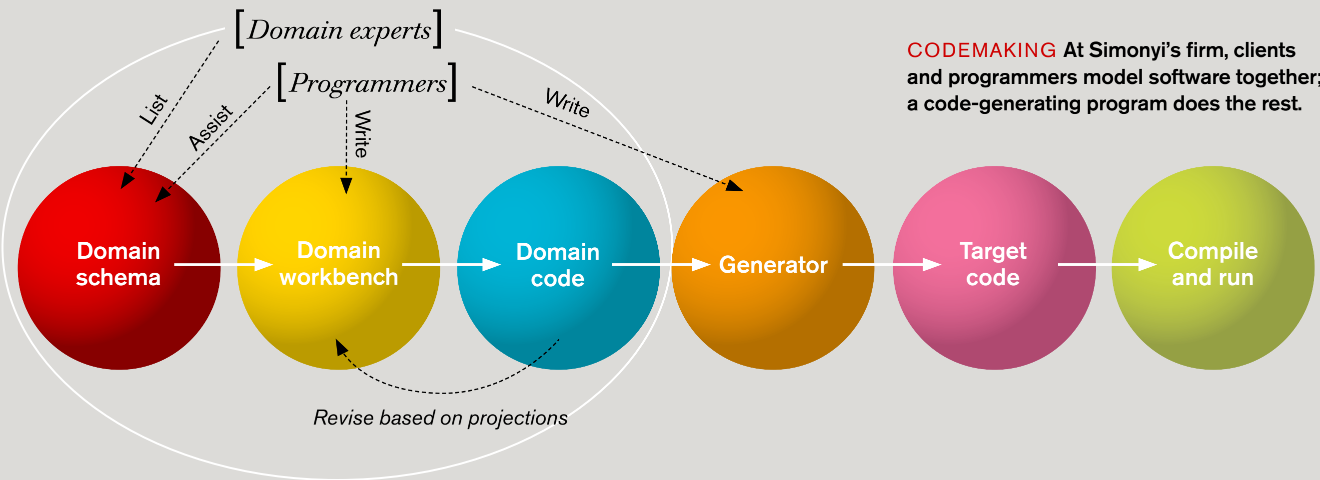
Levels of Abstraction

Wysiwyg is an example of a layer of abstraction—a higher-level tool that allows computer users to ignore some lower-level complexity. Programmers use abstractions all the time. The text code written in a programming language is an abstraction of the machine code that a computer actually understands. A Web domain name is an abstraction of a server's numerical Internet Protocol address.

But most of the layers of abstraction in computer systems are less visible and more arcane than Wysiwyg. Ever since programmers stopped memorizing the opcodes that Simonyi used in his youth, they have been layering new abstractions upon older abstractions. Every generation of programmers uses its era's programming languages and tools to build the programs of the next generation. Layers of abstraction have accumulated like geological strata. Messages are constantly racing up from the binary bedrock of your machine and back down again, making it possible for a mouse-click to accomplish its function. Your mouse-click triggers some code in the operating system, which sends a message to the word processing program, which instructs the operating system to save your file to a hard drive. But that apparently simple process is possible only because of many, many layers of abstraction.

The history of software is the history of these layers, each of them lifting programmers farther from the binary, leaving them better able to coax computers into performing useful tasks. Steadily, programmers gained more power. But they were also tackling ever more ambitious problems. Programs ballooned in size, and programmers started getting lost in tangles of what they called "spaghetti code," which proved impossible to unravel and repair. Thus, large software projects became epics of frustration and delay. Program managers faced business problems like, How do you realistically schedule a project? How do you improve individual productivity? How do you coördinate complex work across a large team? Each of these questions proved surprisingly difficult to answer.

Continued on page 44



CODEMAKING At Simonyi's firm, clients and programmers model software together; a code-generating program does the rest.

Intentional Programming Explained

Simonyi and company are pioneering a push-button approach to programming.

Shane Clifford, a developer at Intentional Software, tells this fable.

Once there was a village with four parks, maintained by four competitive neighborhood associations. The first association decided to spruce up its park with a new bench. It solicited proposals from three of the world's leading bench makers. None of the designs won a majority of the neighbors' votes, so the association chose the most popular design. The process was democratic—but in the end, most were unhappy with the new bench.

The second association decided it wanted its own bench, but one that everybody liked. It found a manufacturer that built customized benches from mix-and-match parts. But the wood seat the members liked didn't come in the right length, and the decorative back didn't work with the green legs they liked. So they compromised on parts that did work together. The neighbors were proud of the finished bench, but no one sat on it very often.

The members of the third association saw how much money the first two had spent and decided they could do better. The craftsmen in the group asked everybody for suggestions, and in the end they built a simple, elegant bench that everyone agreed was the nicest in the village. Unfortunately, it wobbled dangerously.

The fourth association wanted a bench, too, but it didn't want to repeat the other groups' mistakes. The neighbors turned to a little-known bench maker who advertised "a new bench-making experience." The bench maker arrived with a flatbed truck loaded with odd-looking machines. He began to ask questions like "What is this bench's most important feature? What's the next-most-important feature? What materials do you like? What's your favorite shape for the bench's feet?"

After each answer, the bench maker would turn a few knobs on his machines, and a new image of the bench-in-progress would appear on a large screen. Sometimes the image wasn't quite right, so the neighbors would backtrack and answer the questions differently. After 50 questions, the bench maker pushed a large button. The machines hummed for a while, then disgorged a beautiful bench matching the final image on the screen. Everyone was glad to have had a chance to contribute, and many people sat on the bench every day.

To get a bench that makes everyone happy, you must build an automatic bench-making machine; help clients define their precise hopes for their bench; translate those hopes into instructions the bench-making machine understands; and then press the "Make" button. Clients get close control over the outcome, and bench makers, freed from the repetitive and mechanical parts of bench making, get to spend more time using their skills to feed their clients' wishes into the machine.

Substitute software for benches, Clifford is saying, and you'll understand intentional programming—so named because programmers are focused on the way their customers intend a program to work, and not on the clutter of code required to implement those intentions.

Intentional programming is similar in concept to what-you-see-is-what-you-get word processing programs, which Charles Simonyi, Clifford's boss, pioneered. "Wysiwyg" text editors let computer users manipulate a document's appearance on screen without forcing them to master the underlying code. Similarly, intentional programming encourages computer users to express their needs in their own familiar language, then shows them comprehensible views or "projections" of the emerging design before the executable code is assembled. It's not the only programming philosophy that relies on such graphical representations; the Unified Modeling Language (UML), developed in the mid-1990s at Rational Software (now part of IBM), also uses graphical diagrams to represent a program's function, structure, and behavior. But UML diagrams can't be transformed into finished software, which is Simonyi's dream for intentional programming.

Just how does Intentional Software hope to realize that dream? Let's put Simonyi's plan into its own diagram (see above). The software-building process begins, naturally, with the customer: any

organization with an information-intensive task that needs automating. Simonyi calls the people at these organizations "domain experts"; they, not the programmers, know what the program should do.

With the programmers' help, the domain experts list all the concepts and definitions the software will need to encompass. All these definitions go into a database that Simonyi calls the "domain schema."

Like the bench maker turning his knobs, the programmers then incorporate the definitions in the domain schema into "domain code"—a high-level representation of the software's functions, expressed in a "domain-specific language," or DSL, that can be tailored to suit the industry in question. But while DSLs can vary, each action the software must carry out is stored in a uniform format, an "intentional tree." Intentional trees have the advantage of being visually simple but logically comprehensive, which means they can be manipulated, revised, and "projected" or reënvisioned at will.

For example, the computation represented by the simple program statement

```
return a = b / (c +1) ;
```

is represented by the following intentional tree:

```
Return
(
    Assign
    (
        a,
        Div
        (
            b,
            Plus
            (
                c,
                1
            )
        )
    )
)
```

Once encoded in tree form, the computation can be projected in many other ways that might be more familiar to domain experts, such as

```
            b
return a = ---- ;
           c+1
```

As their first concrete task, Simonyi and his colleagues at Intentional Software are working on building a special tool, the Domain Workbench, designed to manage these projections. Both the domain experts and the programmers use the Domain Workbench to edit and reëdit the projections until they look right. After that, the domain code is fed into a "generator"—the equivalent of the bench maker's truckload of machines—that churns out "target code" in a language such as C++ or Java that other computers are able to understand, compile, and run.

Once the target code is generated, it can't be turned back into domain code. In that respect, the generator is like an encryption program that irreversibly transforms plaintext into ciphertext.

However—and this is perhaps intentional programming's biggest advantage—it's easy to scrap old target code and generate improved code from scratch. Simply revise the domain code using the Domain Workbench's Wysiwyg editor and run it through the generator again. In most older approaches, even the slightest change in the original assumptions might require programmers to sift through millions of lines of code, updating every instance of a concept, definition, or computation by hand.

The generator remains the biggest black box in Intentional Software's process. In technical publications, all the company will say about this mysterious component is that the prototype is being written in Microsoft's C# programming language and that it accesses the domain schema and the domain code using an "application programming interface," a way for two programs to communicate, that's built into the Domain Workbench. Clearly, though, writing the generator itself, or tailoring it for a specific industry or DSL, will be a big part of the cost of any intentional-programming project.

"Wysiwyg empowered millions of more users to author great-looking documents," Simonyi writes on the company's blog. "It is time to do the same for software users." **Wade Roush**

The difficulty of coördinating a team's work inspired software engineering's most famous dictum, known as Brooks's Law: "Adding manpower to a late software project makes it later." Frederick P. Brooks Jr. reached this gloomy conclusion after leading IBM's troubled effort to write software for its 360 mainframes in the 1960s. In his 1975 book, *The Mythical Man-Month*, Brooks observed that work proceeds slower on bigger teams because of "coördination costs"—the time programmers lose keeping one another apprised of their work.

This was the backdrop for Simonyi's 1977 dissertation, "Meta-Programming: A Software Production Method." Simonyi proposed a new approach to "optimizing productivity," in which one lead programmer, or "meta-programmer," designed a product and defined all its terms, then handed off a blueprint to "technicians," worker-bee programmers who would do the implementation. Simonyi aimed to escape Brooks's Law by forbidding the technicians to talk with one another: all communication had to pass through the meta-programmer. For his dissertation, he tested the idea using two groups on two projects, A and B. His despotic approach to programming never caught on, but that hardly troubled him. Simonyi's chief goal in researching his dissertation wasn't to prove the value of his ideas but to get Bravo, the new Wysiwyg word processor, written faster. He couldn't persuade the PARC brass to hire additional programmers, so he used his dissertation as a subterfuge to bring in some help. Bravo itself was project B.

As the 1970s wore on, Simonyi grew impatient with Xerox's inability to turn PARC's pioneering research into successful products. One day a friend showed him VisiCalc, the new spreadsheet program for the Apple II. It thrilled Simonyi. Here was another application, like Bravo, that could change people's lives, but unlike Bravo, it ran on a mass-market computer that people could afford to buy. PARC's work, he realized, was never going to see the light of day. He asked his former PARC colleague Bob Metcalfe, who'd left the lab in 1979 to start 3Com, to recommend prospective bosses in the fledgling PC industry. At the head of the list was Bill Gates.

In 1981, Simonyi moved to Seattle to start the new-applications group at Microsoft, which until then had sold programming languages and operating systems. He was 33, but that made him a grown-up among Microsoft's striplings (Gates was then 26 years old, Steve Ballmer 25).

Through all the years that Simonyi oversaw the products that eventually coalesced into the "program suite" known as Microsoft Office, he continued to seek new efficiencies in new kinds of programming abstractions. Most notably, he schooled generations of Microsoft programmers in the discipline of keeping track of the myriad variable names used in big programs. In computer programming, variables represent information that can change as a program runs. For example, an online store's shopping-cart program will have variables that represent the number of items of each type to be purchased, each item's price, and the shipping costs and taxes. Using those variables, a programmer can write a simple line of code that multiplies quantity by price, adds shipping and taxes, and calculates the total cost—which becomes the value of yet another variable.

BRIAN SMALE

HIGH FLIER: **Simonyi in the helmet he will wear on his trip to the International Space Station. He is paying about $20 million for his ride in a Russian rocket. The launch is set for April 9.**

A large program can have thousands of different variables that a programming team must keep straight. Naming them carefully becomes crucial. Today, most code features variable names designed to convey meaning to the programmers who will read it—names like NumberOfItems or ShoppingCartTotal. In Simonyi's naming scheme, which he'd invented for his own use years before, every variable name comes with a prefix that tells you useful information about it, like its type (integer, say, or decimal fraction, or string of letters). Some systems limit the length of variable names to eight characters; Simonyi simply left out the vowels.

The resulting code was dense and hard to read. Simonyi's system came to be known as Hungarian notation, both in homage to its creator's birthplace and because it made programs "look like they were written in some inscrutable foreign language," according to programming pioneer Andy

Hertzfeld. Hungarian is widely cursed by its detractors. Canadian Java expert Roedy Green has jokingly called it "the tactical nuclear weapon of source code obfuscation techniques." Mozilla programmer Alec Flett wrote this parody:

```
prepBut nI vrbLike adjHungarian! qWhat's
artThe adjBig nProblem?
```

Hertzfeld, writing about an encounter at Apple with some Hungarian code written by a colleague who'd worked with Simonyi at PARC, said the names "looked like they were chosen by Superman's enemy from the 5th dimension, Mr. Mxyzptlk."

But while critics believe Hungarian makes code illegible, Simonyi remains proud of it and employs it to this day.

Meta-Euphoria

By the early 1990s, Microsoft's success had made Simonyi's fortune. (For several years, *Forbes* has estimated it to be $1 billion.) But he still felt the tug of unfinished business. Software's confusion had made the creation of Office nerve-racking for Microsoft. But now, with computers more powerful than the Alto on every desk and the Internet linking them together, software's crisis was everyone's crisis. Simonyi began to think it was time to go meta again.

"Charles has always tried to build his systems in ways that raise the level of abstraction, so that you can manage the complexity of the system. Because complexity is death," says Chuck Thacker, Simonyi's old colleague from BCC and PARC, who is leading a research project on computer architecture at Microsoft. "And unfortunately, these days, providing the facilities people actually want results in a complex system. We're hanging on with our fingertips right now."

Moving to a position at Microsoft Research, Simonyi began to define the concept of intentional programming, or IP for short. Intentional programming would add an entirely new layer of abstraction to the practice of writing software. It would enable programmers to express their intentions without sinking in the mire of so-called implementation details that always threatened to swallow them. Like the "metaprogrammers" of Simonyi's dissertation, passing instructions to worker-bee coders, the intentional programmer would hand off the scut work—but not to a junior colleague. Instead, intentional programming called for a sort of code factory called a "generator," a program that takes in a set of relatively high-level commands and spits out more-detailed working code. The goal wasn't so much to ease the labor of programming as to let programmers clear their brains of trivialities so they could actually be creative.

From his programming initiation as a teenager punching opcodes into the Ural, Simonyi had been climbing the ladder of abstraction. But he felt he wasn't high enough. In many ways programming still felt primitive. Why were programmers still saddled with incompatible programming-language syntaxes? Why was it so hard to extend their preferred languages into new areas? Why did programmers still work with plain text, arranging a small number of characters into linear strings as they had in the punch-card past? Simonyi's Wysiwyg work had liberated office workers to create and edit complex documents. Engineers and designers were using advanced CAD/CAM tools to design and modify blueprints for skyscrapers and airplanes. Why were programmers, the wizards who'd made all this possible, still pecking out their code one character at a time?

His Microsoft Research team got to work, and by March 1995 they had built a working system for constructing programs using the intentional-programming approach. Simonyi said IP had "achieved complete self-sufficiency": that is, "all future work on IP would be done using IP itself." He rewarded his team with T-shirts emblazoned with one of his favorite pictures from childhood: the image of Baron Munchausen lifting himself and his horse out of a bog by tugging at his own hair. Simonyi announced intentional programming to the world in a September 1995 paper titled "The Death of Computer Languages." It was time, as he later put it, "for the cobbler's children to get some shoes."

Through the 1990s and into the new millennium—while Microsoft fought its wars with Netscape and the U.S. Department of Justice and rode out the dot-com bubble and bust—Simonyi and his team labored and learned.

Meanwhile, beginning in 2001, Microsoft was pushing the armies of developers who wrote software for Windows to adopt a new programming system called the .Net Framework. Unlike intentional programming, .Net was finished, and it required a less radical break from existing programming techniques. Simonyi itched to take his idea out of the lab and put it in front of customers, but that was awkward under the circumstances. He explains, "It was impractical, when Microsoft was making tremendous strides with .Net in the near term, to somehow send somebody out from the same organization who says, This is not how you should do things—what if you did things in this other, more disruptive way?"

Simonyi had been a company man for more than 20 years. But in 2002, he left Microsoft and launched an independent company. He walked out with a patent-cross-licensing agreement that let him use the concepts and ideas of his intentional-programming research but did not permit him to take any of his old code with him. He would have to start writing a new code base from scratch.

Under the banner of his new company, Simonyi dropped the word "programming" and rebranded his project as "intentional software." The basic idea hadn't changed, but now he began to stress the approach's value to non-programmers. Simonyi's pitch went something like this: Today, only the programmer is able to have a direct effect

on the software. "Subject matter experts" or "domain experts"—the people who actually understand what the software needs to do, whether it is medical record keeping, corporate accounting, or climate modeling—can't make changes to their tools; they're forced to "submit a sort of humble request to the programmer." Intentional Software would sell software development tools not just to programmers but to the domain experts who really knew their fields.

Intentional Software's strategy borrows from a trend in programming known as "domain-specific languages" or DSLs—little programming dialects tuned to the needs of specific disciplines. Simonyi praises DSLs but says they don't go far enough. They're hard to create and therefore costly; you end up needing more than one (for a medical billing system, you'd need at least a medical and a financial language); and they're incompatible with one another. Intentional Software's system is like a factory for multiple DSLs that can talk to one another.

Here's how it might work: Suppose an international bank wanted to develop a new system for managing transactions in multiple currencies. First, the bank's own domain experts would define the system's functionality, using their customary terms and symbols and identifying the most important variables ("time" or "value" or "size of transaction") and the most common procedures ("convert holdings from one currency to another" or "purchase hedge against falling value"). Then the programmers would take that information and build a "domain specific" program generator that embodies that information. A separate software tool would allow the domain experts to experiment with different sets of data and ways to view that data as easily as businesspeople today rearrange their spreadsheets.

The programmer wouldn't have to be summoned each time some new development in the world of international banking, or any other domain, required a new software feature. The customer wouldn't feel straitjacketed by a programming language. Everyone would be happy.

Simonyi argues that his approach solves several of software engineering's most persistent problems. Programmers today, he often says, are "unwitting cryptographers": they gather requirements and knowledge from their clients and then, literally, hide that valuable information in a mountain of implementation detail—that is, of code. The catch is, once the code is written, the programmers have to make any additions or changes by modifying *the code itself.* That work is painful, slow, and prone to error. We shouldn't be touching the code at all, Simonyi says. We should be able to design functions and data structures—which intentional programming represents as "intentional trees"—and let the generator modify the code accordingly. (For a more complete description of intentional programming, see "Intentional Programming Explained," p. 42.)

In 2002 Simonyi assembled a new development team; today it includes a dozen programmers, split between Bellevue and Hungary. They began re-creating Simonyi's intentional-programming code from scratch and working

The Law of Leaky Abstractions

Excerpted from *Dreaming in Code: Two Dozen Programmers, Three Years, 4,732 Bugs, and One Quest for Transcendent Software*, by Scott Rosenberg, to be published by Crown Books in January 2007.

Software, we've seen, is a thing of layers, with each layer translating information and processes for the layers above and below. At the bottom of this stack of layers sits the machine with its pure binary ones and zeros. At the top are the human beings, building and using these layers. Simonyi's Intentional Software, at heart, simply proposes one more layer between the machine and us.

Software's layers are its essence, and they are what drive progress in the field, but they have a persistent weakness. They leak. For instance, users of many versions of Microsoft Windows are wearily familiar with the phenomenon of the Blue Screen of Death. You are working away inside some software application like a Web browser or Microsoft Word, and suddenly, out of nowhere, your screen turns blue and you see some white text on it that reads something like this:

```
A fatal exception 0E has
occurred at
0167:BFF9DFFF.
The current application will
be terminated.
```

Eyeing the screen's monochrome look and the blockish typeface, veteran users may sense that they have been flung backward in computer time. Some may even understand that the message's alarming reference to a "fatal exception" means that the program has encountered a bug it cannot recover from and has crashed, or that the cryptic hexadecimal (base 16) numbers describe the exact location in the computer's memory where the crash took place. None of the information is of any value to most users. The comfortable, familiar interface of the application they were using has vanished; a deeper layer of abstraction—in this case, the Windows "shell" or lower-level control program—has erupted like a slanted layer of bedrock poking up through more recent geological strata and into the sunlight.

(Perplexing as the Blue Screen of Death is, it actually represented a great advance from earlier versions of Windows since it sometimes allows the user to shut down the offending program and continue working.

with a handful of customers to test their assumptions and get feedback. A year ago, inspired by a new insight into how to present multiple views of heterogeneous types of data, they threw out a lot of their code and began again. "It's creative destruction," Simonyi says. "At Microsoft, it was fairly hard to do that, to throw away everything. But you have to abandon things that are difficult to extend."

ThoughtWorks, a global IT consultancy, is one early Intentional Software customer. But ThoughtWorks' CEO, Roy Singham, says that many of his colleagues at the company were initially skeptical of Simonyi's new project: "A lot of people look at this and say, 'Brilliant concept—but it's unimplementable.' So we asked some of our best technical brains to go look, and they all came back and said he's on the right track. Yes, it's hard. Yes, it's going to take time—maybe many years. But intellectually, he's got the thing nailed. It's the right problem to solve."

"I've felt some frustration that we haven't got something we can actually use in production yet," says Martin Fowler, chief scientist at ThoughtWorks. "Charles doesn't seem to be in a hell of a hurry to ship. But one thing to bear in mind is that he has shipped things in the past—quite dramatic things, with Office."

The visible fruit of Intentional's work to date is a nifty tool called the Domain Workbench, which stores a program's vital information in an intentional-tree database and then offers you many different "projections" of that information. In a demonstration Intentional gave at two conferences last fall, the Workbench—using a feature called the Kaleidoscope—took a series of code fragments and displayed them in a dizzying variety of formats. It didn't matter how the syntax of the code had been specified; you could view it, and change it, using whatever notation you preferred. You could edit your program as traditional bracketed and indented code, or switch to outline form, or make it look like a schematic electrical-wiring diagram, or choose something called a "railroad diagram," a kind of flowchart notation derived from old-fashioned train maps. Each view is a translation of the underlying tree—which you can also examine and edit.

Intentional Software's work provokes two main lines of criticism. Some theoretically minded skeptics say Simonyi's goal of capturing computer users' intentions is implausible. "How do you represent intent?" asks computer scientist Jaron Lanier. "As soon as we know how the brain stores information, maybe we can represent intent. To me it just seems like a fantasy." Another argument, common among programmers, is more practical. Many programmers love their text-based editors and distrust tools that distance them from raw code. As for graphical programming languages like Visual Basic and the integrated development environments (IDEs) that automate routine programming tasks, they regard them with condescension: such tools, they say, impose their own ways of doing things, constrain creativity, and keep programmers from the code that, sooner or later, they must confront. (To understand why programmers are so wary, see "The Law of Leaky Abstractions," below.)

Before the blue screen, the crash of one Windows program almost always took down the entire machine and all its programs.)

In an essay titled "The Law of Leaky Abstractions," Joel Spolsky wrote, "All non-trivial abstractions, to some degree, are leaky. Abstractions fail. Sometimes a little, sometimes a lot. There's leakage. Things go wrong." For users this means that sometimes your computer behaves in bizarre, perplexing ways, and sometimes you will want to, as Mitch Kapor said in his *Software Design Manifesto*, throw it out the window. For programmers it means that new tools and ideas that bundle up some bit of low-level computing complexity and package it in a new, easier-to-manipulate abstraction are great, but only until they break. Then all that hidden complexity leaks back into their work. In theory, the handy new top layer allows programmers to forget about the mess below it; in practice, the programmer still needs to understand that mess, because eventually he is going to land in it. Spolsky wrote:

> Abstractions do not really simplify our lives as much as they were meant to. … The law of leaky abstractions means that whenever somebody comes up with a wizzy new code-generation tool that is supposed to make us all ever-so-efficient, you hear a lot of people saying, "Learn how to do it manually first, then use the wizzy tool to save time." Code-generation tools that pretend to abstract out something, like all abstractions, leak, and the only way to deal with the leaks competently is to learn about how the abstractions work and what they are abstracting. So the abstractions save us time working, but they don't save us time learning. … And all this means that paradoxically, even as we have higher and higher level programming tools with better and better abstractions, becoming a proficient programmer is getting harder and harder.

So even though "the abstractions we've created over the years do allow us to deal with new orders of complexity in software development that we didn't have to deal with ten or fifteen years ago," and even though these tools "let us get a lot of work done incredibly quickly," Spolsky wrote, "suddenly one day we need to figure out a problem where the abstraction leaked, and it takes two weeks."

The Law of Leaky Abstractions explains why so many programmers I've talked to roll their eyes skeptically when they hear descriptions of Intentional Programming or other similar ideas for transcending software's complexity. It's not that they wouldn't welcome taking another step up the abstraction ladder; but they fear that no matter how high they climb on that ladder, they will always have to run up and down it more than they'd like—and the taller it becomes, the longer the trip.

Skeptical programmers look at Intentional Software and see the prospect of just another IDE. To those who think that real programmers write text, intentional programming is neither very original nor much wanted.

But mostly, there's surprisingly little discussion of Intentional Software in the Internet's teeming coder forums. In part, that's because so few have seen its software. Intentional's work has proceeded with some secrecy.

When he started Intentional Software, Simonyi partnered with a University of British Columbia professor named Gregor Kiczales. Simonyi admired Kiczales's work on aspect-oriented programming—a way of organizing and modifying code according to "cross-cutting concerns" that resembles intentional programming. Kiczales, another veteran of PARC, has spent his career working on ways to "make the code look like the design." Kiczales saw joining Simonyi as a chance to further that end. But Kiczales trusted open-source development, where Simonyi did not. The Microsoft-style closed-shop approach simply didn't feel "organic" to Kiczales. "I would have done it in Java," he says. "The first release would have been in six months." The disagreement was friendly but irreconcilable, both men say, and before long, Kiczales had left.

Simonyi announced intentional programming to the world in a September 1995 paper titled "The Death of Computer Languages." It was time, as he later put it, "for the cobbler's children to get some shoes."

For now, sheltered by Simonyi's wealth, Intentional Software has no target date or shipping deadline. But one of its two main customers claims to be close to deploying Intentional tools. Capgemini—a Paris-based international IT services and consulting firm that serves large enterprises and whose CTO, Andy Mulholland, is an acquaintance of Simonyi's—began working with Intentional last March and is considering using Intentional's system for projects in the European pensions business. The field's "very complex rules, intertwined with complex business domain structure," make Simonyi's approach look attractive, says Henk Kolk, Capgemini's financial-services technology officer, who is leading the firm's work with Intentional.

Ground Control

Simonyi's fascination with space has been lifelong. As a 13-year-old, he won a competition to become Hungary's "Junior Astronaut" and traveled to Moscow to meet a cosmonaut. As a new hire at Microsoft in 1981, he convinced cofounder Paul Allen to play hooky from developing the IBM PC's new operating system and fly to Florida to watch the space shuttle's first flight.

Simonyi's coming blastoff offers him a full-circle reunion with the Soviet-era technology that set his life's course. He has been training for months at Russia's Yuri Gagarin Cosmonaut Training Center in Star City, mastering the details of space suits and space toilets, and learning Russian.

The space trip will confirm Simonyi's status as that highly unlikely thing: a celebrity programmer. He has two jets and a pilot's license to fly them. He turns up in the tabloids as the frequent companion of homemaking's high priestess, Martha Stewart. He has built a 233-foot yacht with a wraparound glass-walled deck. He has funded an Oxford professorship for his friend Richard Dawkins, the Darwinian theorist.

None of this, of course, will make any difference in the outcome of Simonyi's quest to alleviate the chronic woes of the software field. "It's not enough to be a great programmer," Simonyi once told Michael Hiltzik, author of a history of PARC. "You have to find a great problem." Intentional might never deliver on its grand promises. But no one can charge Simonyi with choosing too modest a problem.

His home these days is a mansion on Lake Washington, down the shore from Bill Gates's house, with an art gallery, a glass-enclosed swimming pool, a heliport, a computer lab with magnetically lined walls, and a lathe and drill press in the basement (to fulfill those Erector Set cravings). The house cost $10 million to build: it is tilted at a seven-degree angle and "looks like a slight earthquake hit it," in the words of *New York Times* writer Patricia Leigh Brown, who marveled at its "hermetically sealed, mathematical precision" and found it "so vast that a visitor can feel like a lonely asteroid rattling around the solar system."

"[Only] Charles would build a 20,000-square-foot home with one bedroom," Simonyi's dissertation advisor and PARC colleague Butler Lampson once remarked. The lone bedroom boasts a cockpit-like control center that lets Simonyi tweak all his systems—heating, entertainment, telephone, lighting, and watering—to his satisfaction. "Like a submarine," he explained to Brown. "They all have to be green before you submerge." There's also a pivoting bed, which Simonyi can use to fine-tune his view—out across the lake; or over to the Seattle skyline, with its warrens of office workers wrestling with their documents and spreadsheets; or up into the starry night sky, where his latest journey will soon take him. TR

Scott Rosenberg is vice president of special projects at Salon.com. He is the author of Dreaming in Code.

Innovation, leading-edge information, and opportunity— all wrapped up into one spectacular week.

JANUARY 22 - 26, 2007

TECHNOLOGY INVESTING WEEK IN PALM SPRINGS, CALIFORNIA

6TH ANNUAL

Nanotech Investing Forum

JANUARY 22 & 23

A CONFERENCE WHERE VENTURE CAPITALISTS, CORPORATE INVESTORS AND NANOTECH CEOs UNITE. THE NANOTECH INVESTING FORUM WILL PROVIDE LEADING-EDGE INFORMATION TO PROFIT FROM NANOTECH INNOVATION AND WILL ENABLE YOU UNPARALLELED NETWORKING OPPORTUNITIES!

3RD ANNUAL

Clean Tech Investor Summit

JANUARY 23 & 24

CLEAN AIR HAS GARNERED CONSIDERABLE RECOGNITION AS A GROWTH SECTOR. THE INCREASE IN RECENT DEAL FLOW, START-UP ACTIVITY, AND CORPORATE ANNOUNCEMENTS HAS LED TO EXTENSIVE ANALYST & MEDIA COVERAGE THAT IS CAPTURING THE ATTENTION OF THE VENTURE INDUSTRY. PRESENTED BY IBF AND CLEAN EDGE, THIS CONFERENCE WAS A SELL OUT IN 2005!

9TH ANNUAL

Corporate Venturing & Strategic Partnering Conference

JANUARY 25 & 26

CAPTURING INNOVATION, MARKET SHARE AND REVENUE STREAMS THROUGH CORPORATE VENTURE CAPITAL, M&A, AND CORPORATE DEVELOPMENT PARTNERSHIPS. HERE'S YOUR OPPORTUNITY TO LEARN AND SHARE BEST PRACTICES, INVESTMENT STRATEGIES TO GAIN COMPETITIVE ADVANTAGE!

Attend one or all!

For more information or to register please go to www.ibfconferences.com and mention discount code: AdTechR *to receive a $100.00 discount off the regular registration rates.*

International Business Forum
IBF
Conferences

575 Broadway Massapequa, Long Island, NY 11758 T: 516 765-9005 F: 516 765-9015 www.ibfconferences.com

Raising Consciousness

Some seemingly unconscious patients have startlingly complex brain activity. What does that mean about their potential for recovery? And what can it tell us about the nature of consciousness?

By Emily Singer

In 2003, 39-year-old Terry Wallis uttered his first word ("mom") in the 19 years since a car accident had left him with severe brain damage. He had spent much of the previous two decades in what neurologists call a minimally conscious state, somewhere in the gray area between coma and consciousness. In the years before his awakening, however, Wallis's family had noticed that he was growing more alert and responsive, occasionally nodding, grunting, or even crying, until one day he spontaneously started to speak. Though Wallis still has serious impairments in memory and movement, he continues to make remarkable gains.

No one knows what spurred Wallis's return to the waking world. But neurologist Nicholas Schiff is determined to find out. A researcher at the Weill Cornell Medical College in New York City, Schiff is one of a handful of scientists studying people like Wallis, patients who spend months or years seemingly unaware of the outside world and unable to communicate. Using new brain-imaging techniques, Schiff is hoping to better understand the complex nature of consciousness—and find ways to help treat the thousands of patients who suffer from severe consciousness disorders.

Eight months after Wallis's first words, Schiff and his collaborators began taking snapshots of Wallis's brain using a new method that can create detailed maps of the brain's nerve fibers. What they found surprised them. Over the next year and a half, the researchers' images seemed to show that Wallis's brain had partially healed itself. But how? And what triggered the healing process?

In the last few decades, improved medical technologies have kept more people alive after brain injuries, but many of them have been left in apparently permanent states of impaired consciousness. Immediately after a severe brain injury, a patient often enters a coma—a period of unconsciousness that typically lasts days or, at most, weeks. Those who survive do not necessarily awaken; instead, they may enter a vegetative state or a minimally conscious state (MCS), which can last for years. While it's difficult to determine how many minimally conscious patients there are in the United States (MCS was introduced as a diagnostic category only in 2002), some estimates put the number at 25,000 or more—about 10 times the number of vegetative patients. (The two conditions can be difficult even for neurologists to distinguish. Vegetative patients are defined as those totally unaware of their environment, while patients who are in a minimally conscious state may occasionally laugh or cry, reach for objects, or even respond to simple questions.)

Unlike Wallis, most patients who spend years in a minimally conscious state never wake up. Prospects for recovery diminish as time ticks by, so many doctors adopt a sort of therapeutic nihilism toward those who are persistently unconscious, assuming that their cases are hopeless, says Steven Laureys, a neurologist at the University of Liège in Belgium. MCS patients have few treatment options, and most don't get rigorous long-term follow-up or intensive rehabilitation. Wallis, for example, had no neurologist, and not much medical history was collected during his 19-year hiatus from consciousness.

However, recent studies from Schiff's lab and others have shown that at least some of these seemingly unaware patients have a startlingly high level of brain activity, mentally reacting to stories and commands much as a healthy person would. Schiff and others who study minimally conscious patients are careful to distinguish them from patients such as Terri Schiavo, who received nationwide media attention in 2005. Schiavo was in a vegetative state, which she entered after lack of oxygen led to widespread brain-cell death. When a brain injury is caused by trauma,

on the other hand, the damage is often limited to the nerve fibers that connect different parts of the brain, and some neural circuits may remain intact. Among these patients, the new imaging studies are revealing a surprising potential for some restoration of normal brain activity.

The findings offer hope for a group of people largely given up for lost by the medical community. Schiff and others are working to piece together the structural or functional changes that enable some MCS patients to awaken; eventually, the researchers hope to design treatments that can spur those changes in others. At the same time, they are opening a window on a hidden world. "Consciousness is a subjective, first-person experience," says Laureys. "It is very tricky to conclude the absence of consciousness based on the absence of response at the bedside. There might be some inner world that we have no way to assess."

Mental Tennis

In 1998, Joy Hirsch, a neuroscientist at the Columbia University Medical Center in New York City, paved the way for studies that use functional MRI (fMRI) to assess impaired consciousness. By measuring blood flow in the brain, fMRI can pinpoint regions that are active when, for example, a person is feeling anger or working on an abstract problem. Hirsch wanted a way to locate—and thus protect—the language area in babies who needed brain surgery. While most previous fMRI studies had required volunteers to perform specific tasks, such as reading or speaking, to activate the relevant parts of the brain, Hirsch found that just reading a story to the babies could stimulate the region involved in speech. It became obvious, she says, that the same technique could be used to test cognitive function in minimally conscious patients.

Aided by further improvements in imaging technology, in 2005 Hirsch and Schiff used fMRI to examine how two minimally conscious patients responded to stories told by friends and family members. The results were similar to those seen in healthy volunteers. The stories triggered activity in the language centers and other areas of the brain, suggesting that certain clusters of neurons remained intact and functioning. When a patient listened to his sister tell stories about their childhood, for example, parts of his visual system lit up, suggesting that he might be imagining those scenes.

The findings sparked intense interest among neurologists, but without direct reports from the subjects themselves, it was difficult to judge exactly what the patients were experiencing. Were they trapped in a lonely mental prison, aware of the world outside but unable to respond to it? Did they experience only isolated moments of awareness? Or was the brain activity simply a sort of cognitive reflex, triggered by a familiar voice and a few evocative words or names?

In 2005, Adrian Owen, a neuroscientist at the Medical Research Council in Cambridge, England, began a series of experiments to address these questions. Owen and his coworkers created a brain-imaging test they hoped would indicate whether someone was actually aware of his or her environment. An MCS patient was instructed to imagine playing tennis when she heard the word "tennis," or to imagine walking through her house when she heard the word "house"; she was then positioned in the scanner and given auditory prompts. The test was designed to evaluate both short-term memory, because the instructions were given well before the prompts, and the capacity for sustained attention, because the patient was told to continue imagining a scene until asked to stop. Most important, it was designed to require intentional action.

If you're healthy, imagining that you're playing tennis or navigating your house activates specific parts of your brain—respectively, the supplementary motor areas, which control motor responses, and the parahippocampal gyrus, which plays a role in memory of scenes. So the scientists knew exactly what to look for in patients with impaired consciousness. Their subject was a 23-year-old woman who'd been left in a vegetative state after a car accident in 2005. At the time of the study, five months had elapsed since her accident, meaning that statistically, she had a 20 percent chance of some recovery. She showed no outward signs of awareness.

The results of the test were shocking, even "spectacular," according to a commentary accompanying their publication in the journal *Science* last fall. "When we cued her with the word 'tennis,' her brain would activate in a way that is indistinguishable from a healthy person," says Owen. The same was true for the word "house." "We think the fMRI demonstrated unequivocally that she is aware," he says.

While the patient met all the clinical requirements for being in a vegetative state, her fMRI clearly showed a brain capable of relatively complex stimulus-processing. Still, it's not yet certain what conclusions can be drawn from her case. "We have studied over 60 patients in Belgium and have never seen activation compatible with conscious perception," says Laureys. "I definitely think this is the exception, but I can't tell if it's a one-in-a-thousand or a one-in-a-million case." Owen now plans to run the same tests on more patients, using a variation of fMRI that shows brain responses in real time.

Perhaps the most perplexing question raised by the results concerns the patient's state of mind: is she truly conscious? That's a matter of some debate: Owen believes the patient was aware of herself and her surroundings, but other neurologists aren't so sure. "No one knows what she really was thinking during scanning," says Laureys.

The answer may come with Owen's next round of experiments, which are designed to perform what some consider

the best test of consciousness—asking a person about his or her state of mind. Using real-time fMRI, scientists can ask patients questions and gauge their responses on the basis of their brain activity. For example, since scientists know the activity patterns associated with imagined games of tennis and walks through houses, they could tell their patients to think of tennis for yes and house tours for no, then ask binary questions while performing brain scans.

Like Schiff and Hirsch's findings, Owen's are both fascinating and disquieting, largely because neurologists don't yet know what to do with them. Does the brain activity of the woman Owen studied mean she will soon wake up? What about other patients with similar injuries? Schiff, for one, plans to see if some of his patients who show visible signs of awareness can replicate Owen's results. "My guess is that some of them will be able to do it," he says.

Lesions of Consciousness

We'll probably never know whether Terry Wallis also had some awareness before his awakening. But a type of brain imaging known as diffusion tensor imaging (DTI) has given researchers hints about how his brain has changed since.

DTI is a variation of MRI that offers an unprecedented view of the brain's wiring system—the long, thin tails of neurons that carry electrical signals between different regions. Wallis's first DTI scan, recorded eight months after his first word, revealed that he had profound brain damage. But scientists also discovered possible signs that new neural connections had sprouted between brain structures. In particular, a large area in the back of his brain appeared to have more neural fibers than normal, all oriented in the same direction. The area encompassed by these new fibers included a part of the brain known as the precuneus, which is highly active during conscious wakefulness but less active during sleep or anesthesia.

Eighteen months after that scan, Wallis was doing even better. He could move his previously paralyzed legs, an improvement "as unexpected as him recovering speech," says Schiff. When the researchers imaged his brain a second time, they found that the unusual area in the back had normalized, while a region involved in regulating movement seemed to have grown more connected. The findings were published last year in the *Journal of Clinical Investigation*.

The researchers can't yet be sure that the changes they saw in the brain images really do indicate the growth of new neuronal connections, nor that those changes sparked Wallis's recovery. "Why did he emerge? None of us can answer this," says Hirsch. "But it suggests a biological underpinning to recovery."

Brain imaging might eventually be used as a diagnostic tool to help spot those who are most likely to recover. "We need to develop better ways to model and measure the emergence to consciousness and collect enough data so that we can make statistical predictions for recovery," says Schiff. However, identifying the telltale changes that predict awakening promises to be difficult. Schiff and Hirsch have scanned more than a dozen other patients in addition to Wallis, including several who have awakened, and they have yet to find specific patterns or changes in brain activity that might signal that a patient is improving. But they're still looking—at whether the network hubs of the brain are active, for example, or whether activity in different brain areas is in sync. "We think of patients with traumatic brain injury as patients with lesions of consciousness," says Hirsch. She hypothesizes that consciousness arises from a network of connections rather than in a specific location in the brain.

The brain is constantly processing information: sights and sounds are recorded and synthesized in different parts of the brain, then fused together in other areas, creating a cohesive picture of the outside world. And early evidence indicates a link between consciousness and the ability to integrate information. In a study of 60 patients in the vegetative state, Laureys found that the seven patients who later awakened recovered brain metabolism in regions that connect the cortex with the thalamus, a relay center in the brain.

> Without direct reports from the patients, it was difficult to judge exactly what they were experiencing. Were they trapped in a lonely mental prison, aware of the world outside but unable to respond to it?

Injury to the brain may tear the nerve fibers that relay messages between different regions, impeding the integration process. Similarly, Schiff believes that the circuits left intact in minimally conscious and vegetative patients may communicate erratically, making it difficult for the brain to coördinate complex tasks involving multiple brain areas. Patients with impaired consciousness also exhibit low levels of neural activity, Schiff says; their brains may take a stab at a particular task, generating the brief appearance of responsiveness, but then peter out. A patient's occasional moments of clarity, then, might come from brief spurts of synchronized activity. "Some patients may harbor the capacity for functional recovery, but it depends on recruiting circuit-level neuronal responses to sustain a state like that of the brain working normally,"

Schiff says. Emotional events, such as a sister's description of childhood memories, may do a better job of activating those circuits, which could explain why emotional stories seem to trigger the strongest responses.

Understanding what causes impairments in consciousness could ultimately shed light on a larger puzzle: what allows a healthy person to be aware of self and surroundings? "I think that a detailed understanding of the necessary and sufficient conditions for the recovery of consciousness will provide immensely important insights into the fundamental nature of the human conscious state," says Schiff.

Abandoned

Schiff's ultimate goal, of course, is to spark awakenings like that of Terry Wallis in other minimally conscious patients. At a neuroscience meeting last October, he presented preliminary evidence that electrically stimulating the thalamus, which sends sensory information to the cerebral cortex, might help patients recover consciousness. Schiff and his team used deep brain stimulation—a therapy used to treat Parkinson's disease, where an electrode is implanted in the brain—to stimulate thalamic neurons in a 38-year-old minimally conscious patient who had suffered a severe traumatic brain injury six years before. They found that when the neurons were stimulated, the patient was more responsive and coördinated, even able to eat a meal with some independence.

Schiff says the families of patients enrolled in his studies often thank him for being interested at all. "Their uniform experience is that no one cares," he says. "They are completely abandoned by people who would otherwise have taken care of them."

Though Schiff is reluctant to talk about his group's findings before they are published in a peer-reviewed paper, he and other neurologists are clearly excited about them. "This is a very interesting and important observation," says James Bernat, a neurologist at Dartmouth Medical School, who adds that Schiff's result is particularly noteworthy because the patient had been in a minimally conscious state for so long. Previous studies of deep brain stimulation, carried out mostly in Japan, have involved recently injured patients, who might have improved anyway.

To prove the efficacy of deep brain stimulation in treating consciousness disorders, and to determine just which patients it might help, other researchers will need to duplicate Schiff's success. But that's a tall order. Research on minimally conscious and vegetative patients presents enormous obstacles—the logistics of transporting patients from long-term-care facilities to imaging labs, the ethical and legal issues involved in testing people who cannot give informed consent, and the technical challenge of scanning patients who may move unpredictably and may not be able to comprehend instructions to stay still.

But the biggest barrier to larger studies is funding. Terry Wallis is one of the most remarkable recovery cases Schiff has ever seen. And yet he's examined him just twice: first when a British television station flew Wallis and his family from Arkansas to New York, where Schiff and collaborators could scan his brain; and then when the producers of an HBO documentary paid Wallis's fare to New York 18 months later, so that scientists could assess the changes that had taken place since the first scan.

One might expect that some of the exciting research with minimally conscious patients in the last two years would bring more money to the field, but that has yet to happen. In early November, Schiff received disappointing news: the National Institutes of Health, the primary biomedical funding agency in the United States, had declined to fund larger studies of the diagnostic methods he and others have been developing. He says that while some grant reviewers are excited by the recent findings, others are reluctant to spend money on a group of patients they see as beyond hope. "I think it shows a discriminatory bias against this patient pool," says Schiff.

Neurologists studying disorders of consciousness say fatalism about their patients' prospects extends far beyond the walls of funding organizations. Wallis's family, for example, petitioned for a neurologist annually for 19 years without success. And Schiff says the families of patients enrolled in his studies often thank him for being interested at all. "Their uniform experience is that no one cares," he says. "They are completely abandoned by people who would otherwise have taken care of them."

If Schiff and others are right, this population of abandoned patients includes many people aware of their surroundings. And Wallis's recovery serves as an example of just how much some of these patients might be able to improve if they can be gently prodded back to the world of full consciousness. As Wallis works diligently on his rehab exercises, Schiff continues his dogged search for clues as to how to spark such a recovery in others, coming ever closer to understanding the mysteries of consciousness. TR

Emily Singer is the biotechnology and life sciences editor of Technology Review.

Lowest price ever…$49.95!

A floor lamp that spreads sunshine all over a room, and pays for itself!

CALL TODAY TO RECEIVE FREE SHIPPING*

*The Balanced Spectrum® floor lamp combines the benefits of natural daylight indoors with a savings of $77 over the life of one bulb!***

Ever since the first human went into a dark cave and built a fire, people have realized the importance of proper indoor lighting. Unfortunately, since Edison invented the light bulb, lighting technology has remained relatively prehistoric. Modern light fixtures do little to combat many symptoms of improper lighting, such as eyestrain, dryness or burning. As more and more of us spend longer hours in front of a computer monitor, the results are compounded…and the effects of indoor lighting are not necessarily limited to physical well-being. Many people believe that the quantity and quality of light can play a part in one's mood and work performance. Now there's a better way to bring the positive benefits associated with natural sunlight indoors.

The Balanced Spectrum® floor lamp will change the way you see and feel about your living or work spaces. Studies show that sunshine can lift your mood and your energy levels. But as we all know, the sun, unfortunately, does not always shine. So, to bring the benefits of natural daylight indoors, use the floor lamp that simulates the full spectrum of daylight. You will see with more clarity and enjoyment as this lamp provides sharp visibility for close tasks and reduces eyestrain.

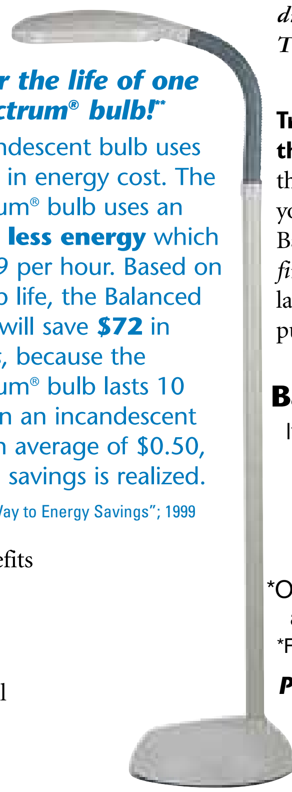
Its 27-watt compact bulb is equivalent to a 150-watt ordinary light bulb. This makes it perfect for activities such as reading, writing, sewing, needlepoint, and especially for aging eyes.

Experience sunshine indoors at the touch-of-a-switch. This amazing lamp is easy on the eyes and easy on the hands. It features a special "soft-touch, flicker-free" rocker switch that's easier to use than traditional toggle or twist switches. Its flexible gooseneck design enables you to get light where you need it most. The high-tech electronics, user-friendly design, and bulb that lasts 10 times longer than an ordinary bulb make this lamp a must-have.

SAVE $77 over the life of one Balanced Spectrum® bulb!**

A 150-watt incandescent bulb uses $0.013 per hour in energy cost. The Balanced Spectrum® bulb uses an average of **70% less energy** which saves you $0.009 per hour. Based on 8,000 hours bulb life, the Balanced Spectrum® bulb will save **$72** in energy cost. *Plus*, because the Balanced Spectrum® bulb lasts 10 times longer than an incandescent bulb priced at an average of $0.50, an additional **$5** savings is realized.

**Source: "Lighting the Way to Energy Savings"; 1999



Height as shown: 50"

"As soon as I turned on the lamp and began to read the newspaper I could see the wonderful difference. This lamp is just what I needed. Thank you so much."

Donna E.
Scranton, PA

Try the Balanced Spectrum® floor lamp for the best value ever! Now more than ever is the time to add sunshine to every room in your home at this fantastic low price! The Balanced Spectrum® floor lamp comes with *first*STREET's exclusive guarantee. Try this lamp for 90 days and return it for the product purchase price if not completely satisfied.

Balanced Spectrum® floor lamp

Item# BB-3589 .... **was ~~$59.95~~**

Call now for $10 instant savings!

Only $49.95 each + S&H

*Order two Balanced Spectrum® floor lamps and get **FREE shipping** on both lamps.

*Free shipping within the contiguous 48 states only.

Please mention promotional code 32375.

For fastest service, call toll-free 24 hours a day

1-800-711-8094

We accept all major credit cards, or if you choose, you can pay by check with ClearTran™ over the phone.

To order by mail, please call for details.

www.balancedspectrum.com

*first*STREET®
SEE IT HERE FIRST®

1998 Ruffin Mill Road
Colonial Heights, VA 23834

41456

China's Coal Future

To prevent massive pollution and slow its growing contribution to global warming, China will need to make advanced coal technology work on an unprecedented scale.

By Peter Fairley

A visitor arriving in Shanghai immediately notices China's technological conundrum. Through the windows of the magnetically levitated train that covers the 30 kilometers from Pudong International Airport to Shanghai at up to 430 kilometers per hour, both the progress the country is making and the price it is paying for it are apparent. Most days, a yellow haze hangs over Shanghai's construction frenzy. Pollution is the leading cause of death in China, killing more than a million people a year. And the primary cause of pollution is also the source of the energy propelling the ultramodern train: coal.

To keep pace with the country's economic growth, China's local governments, utilities, and entrepreneurs are building, on average, one coal-fired power plant per week. The power plants emit a steady stream of soot, sulfur dioxide, and other toxic pollutants into the air; they also spew out millions of tons of carbon dioxide. In November, the International Energy Agency projected that China will become the world's largest source of carbon dioxide emissions in 2009, overtaking the United States nearly a decade earlier than previously anticipated. Coal is expected to be responsible for three-quarters of that carbon dioxide.

And the problem will get worse. Between now and 2020, China's energy consumption will more than double, according to expert estimates. Ratcheting up energy efficiency, tapping renewable resources with hydro dams and wind turbines, and building nuclear plants can help, but—at least in the coming two decades—only marginally. Since China has very little in the way of oil and gas reserves, its future depends on coal. With 13 percent of the world's proven

NATALIE BEHRING/REUTERS

reserves, China has enough coal to sustain its economic growth for a century or more. The good news is that China's leaders saw the coal rush coming in the 1990s and began exploring a range of advanced technologies. Chief among them is coal gasification. "It's the key for clean coal in China," says chemical engineer Li Wenhua, who directed advanced coal development for Beijing's national high-tech R&D program (better known in China as the "863" program) from 2001 through 2005.

Gasification transforms coal's complex mix of hydrocarbons into a hydrogen-rich gas known as synthesis gas, or "syngas." Power plants can burn syngas as cleanly as they can natural gas. In addition, with the right catalysts and under the right conditions, the basic chemical building blocks in syngas combine to form the hydrocarbon ingredients of gasoline and diesel fuel. As a result, coal gasification has the potential both to squelch power plants' emission of soot and smog and to decrease China's growing dependence on imported oil. It could even help control emissions of carbon dioxide, which is more easily captured from syngas plants than from conventional coal-fired plants.

Despite China's early anticipation of the need for coal gasification, however, its implementation of the technology in power plants has lagged. The country's electricity producers lack the economic and political incentives to break from their traditional practices.

In contrast, large-scale efforts to produce liquid transportation fuels using coal gasification are well under way. China's largest coal firm, Shenhua Group, plans to start up the country's first coal-to-fuels plant in 2007 or early 2008, in the world's most ambitious application of coal liquefaction since World War II. Shenhua plans to operate eight liquefaction plants by 2020, producing, in total, more than 30 million tons of synthetic oil annually—enough to displace more than 10 percent of China's projected oil imports.

China's progress in constructing coal-conversion plants puts it far ahead of the United States, where coal gasification is still recovering from a damaged reputation. Gasification demonstration programs initiated in the U.S. after the energy crises of the 1970s were orphaned when oil and gas prices plummeted in the 1980s. That left many with the impression that the technology itself was unreliable *(see "Carbon Dioxide for Sale," July 2005)*. In China, by contrast, oil never looked cheap, and coal has never lost its shine.

Coal and Cashmere

Northern China is fast becoming the epicenter of China's energy industry. The leading draw is the Shenfu Dongsheng coalfield, a 31,000-square-kilometer solid layer of shallow coal that stretches from the northern tip of China's Shaanxi Province to the southern edge of Nei Mongol, or Inner Mongolia. The Dongsheng field's estimated reserve

A billboard exhorts construction workers building Shenhua Group's coal liquefaction plant in Inner Mongolia: "To make a better future we must work hard for the project of making coal into oil."

PETER FAIRLEY

of 223.6 billion tons of coal makes it the world's seventh largest; efforts to convert much of that coal to transportation fuels could make it the world's most profitable.

Until recently, Inner Mongolia's coal capital, Erdos, was largely untouched by the modern world, bounded by mountain ranges and the Great Wall to the south and by the Yellow River to the north. Its isolation is now over, thanks to freshly poured highways and new rail lines rolling over its fissured hills and steep valleys. An airport should open this year.

Erdos's GDP doubled between 2001 and 2004, largely because of coal, chemicals, and cashmere (Erdos supplies a quarter of the world's cashmere). To reach the coalfields, you drive 40 minutes south of the city, passing a 1950s-era mausoleum for Genghis Khan, the 13th-century warrior who conquered much of Asia. As you approach the dry floodplain of the Wulanmulun River, the imposing infrastructure of a dozen coal mines, including some of the world's largest and most mechanized, leaps out of the barren landscape. The region is also home to several hundred smaller, less modern mines (gases and cave-ins kill at least 6,000 Chinese coal miners a year). Miners on their day off zip by on mopeds, three or four to a vehicle, racing past 40-ton trucks heaped with coal. Along the highway, coal-sorting terminals load railcars destined for power plants and ports on the industrialized east coast.

None of that infrastructure and activity, however, prepares a visitor for Shenhua's coal-to-fuels complex, which rises from a plateau cut into the hills. It is an impressive site, with its own coal-fired power plant, gasification plants, and two massive reactors where coal will be liquefied, each weighing 2,250 metric tons (Shenhua claimed the world hoisting record when it lifted the reactors into place last June). Flush from a $2.95 billion IPO in 2005 and $5 billion in annual revenues from its integrated mines, railroads, and power plants, Shenhua is rapidly expanding its operations. It sold 113 million metric tons of coal in just the first half of 2006, nearly matching the previous year's total. If Shenhua maintains that pace this year, it may become the world's largest producer of coal.

China's government in Beijing created Shenhua a decade ago to bring economies of scale and modern technology to bear on the Dongsheng coalfields. The company's $1.5 billion coal-to-fuels plant is an expression of that strategy—a facility so technically ambitious that many experts, Chinese and Western alike, doubted it would ever be built.

The production of transportation fuels from coal dates to early-20th-century Germany, where chemists developed two approaches to converting coal's solid long-chain hydro-

carbons into the shorter liquid hydrocarbons found in motor fuels. (Nazi Germany, with little access to oil, relied heavily on these processes to fuel its highly mechanized army and air force, producing gasoline, diesel, and aviation fuel from coal.) Franz Fischer and Hans Tropsch invented the better known of the two approaches in the 1920s. Fischer-Tropsch synthesis reduces coal to syngas, a mixture of hydrogen and carbon monoxide. A catalyst, often cobalt, then causes the carbon and hydrogen atoms to reconnect into new compounds, such as alcohols and fuels. Fischer-Tropsch synthesis is conventional chemistry today: in South Africa, for example, Johannesburg-based Sasol built Fischer-Tropsch coal-to-oil plants to ensure the country's fuel supply during the trade boycotts of the apartheid years; and by swapping in different catalysts, China's coal-to-chemicals gasification plants have employed Fischer-Tropsch for decades to yield products such as synthetic fertilizers and methanol.

Shenhua's plant, in contrast, chose Fischer-Tropsch's lesser-known rival, invented by Friedrich Bergius a decade earlier. Though used extensively by the Nazis, Bergius's process was subsequently abandoned. The process has come to be known as direct liquefaction, because it bypasses the syngas step. In direct liquefaction, the bulk of the coal is pulverized and blended with some of the plant's synthetic oil, then treated with hydrogen and heated to 450 °C in the presence of an iron catalyst, which breaks the hydrocarbon chains into the shorter chains suitable for refining into liquid fuels.

Direct liquefaction produces more fuel per ton of coal than Fischer-Tropsch synthesis. Experts at the Chinese Coal Research Institute in Beijing estimate that the process captures 55 to 56 percent of the energy in coal, compared to just 45 percent for Fischer-Tropsch. However, direct liquefaction is also far more complicated, requiring separate power and gasification plants to deliver heat and hydrogen and considerable recycling of oil, hydrogen, and coal sludge between separate sections of the plant. And breaking down hydrocarbons to just the right length requires exquisite control of the operating conditions and a consistent coal supply.

Shenhua redesigned the process over the last five years to boost efficiency and reduce waste but, at the same time, increased its complexity. And the company is taking a huge engineering and economic risk by pursuing so novel a technology on such a vast scale.

By the end of this year, Shenhua hopes to be pumping out 20,000 barrels of synthetic oil per day, nearly 500 times as much as its pilot plant in Shanghai produces. According to Jerald Fletcher, a natural-resource economist at West Virginia University in Morgantown, the Erdos plant constitutes a $1.5 billion experiment that could only take place in China. "It would be hard to get that kind of commitment of funds in the West without a more proven technology," says Fletcher. Eric Larson, an expert in energy technology and modeling at Princeton University, puts it more bluntly: "It doesn't make a lot of sense to build a huge plant like that, because it may not work."

But for the Chinese government, the rewards could be worth the risk. Despite its 2005 IPO of some assets, Shenhua remains a largely state-owned firm, and the direct-liquefaction plant serves a critical state interest: energy security. "No matter how big the cost, Shenhua will build it," says Zhou Zhijie, a gasification expert at East China University of Science and Technology's Institute of Clean Coal Technology in Shanghai. "China's government will support this project until the liquid flows."

Shenhua's $1.5 billion coal-to-fuels plant is so technically ambitious that many experts, Chinese and Western alike, doubted it would ever be built.

Of course, if the new plant works, Shenhua stands to earn a substantial profit. The company predicts that its synthetic oil will turn a profit at roughly $30 a barrel, though many analysts say $45 is more realistic. (The U.S. Department of Energy's most recent price forecast predicts that crude oil will dip to $47 a barrel in 2014, then climb steadily to $57 a barrel in 2030.) Hedging its bets, Shenhua has also entered a preliminary agreement with partners Shell and Sasol concerning several similar-sized or bigger Fischer-Tropsch fuel plants in Northern China, which would start up in 2012.

Shenhua's Chinese coal competitors, too, are already breaking ground on their versions of coal-to-fuel plants. The Yankuang coal group, the second-largest coal producer in China, is planning a Fischer-Tropsch fuel plant near Erdos that will use a proprietary gasifier and catalyst.

Beyond the risks inherent in the large-scale deployment of unproven technology, the gasification building boom also is an environmental gamble. Indeed, what may ultimately check China's coal-to-oil ambitions is water. China's Coal Research Institute estimates that Shenhua's plant will consume 10 tons of water for every ton of synthetic oil produced (360 gallons of water per barrel of oil), and the ratio is even worse for Fischer-Tropsch plants. Last summer, China's National Development and Reform Commission, the powerful body charged with regulating China's economy and approving large capital projects, issued a warning about the

environmental consequences of the "runaway development" of synthetic-oil and chemical plants, which it said will consume tens of millions of cubic meters of water annually.

That prediction sounds particularly ominous in northern China, where water is scarce. Erdos is a mix of scrub and desert whose meager water supplies are already overtaxed by population growth and existing power plants. Zhou Ji Sheng, who as vice manager of ZMMF, one of Shenhua's Erdos-based competitors, is seeking financing for a gasification project, acknowledges that water scarcity could put an end to coal gasification in the area. "Even though we have so much coal, if we have no water, we will just have to use the traditional way—to dig it out and transport it," he says. "Water is the key factor for us to develop this new industry." Zhou says his firm plans to supplement its water supply by building a 120-kilometer pipeline to the Yellow River. But evaporation from hydroelectric reservoirs, the increased demand of growing cities and industries, and the effects of climate change mean that in the summer, the Yellow River barely reaches the sea.

Carbon Power

While China's desire to end its dependence on foreign oil is helping to drive huge capital investments in liquefaction technology, the country's power producers are moving much more slowly to take advantage of coal gasification. What they, like their American counterparts, are missing is an incentive to upgrade from conventional pulverized-coal plants to the more expensive gasification plants. According to Li Wenhua, the former 863 program manager (who now directs gasification research in China for General Electric), Chinese industrialists perceive pulverized-coal plants as a license to print money. "People say you shouldn't call it a power plant; it's a money-making machine," says Li. As yet, no power company has been willing to be the first to hit the off switch.

Ironically, China's move to a more open economy has hampered efforts to deploy more innovative technologies. In the 1990s, it looked as if China's power sector was headed for its own gasification revolution. In 1993, China's leading power engineering firm, China Power Engineering Consulting in Beijing, began designing the country's first gasification power plant. The monopoly utility of the era, the State Power Corporation, planned to build the commercial-scale plant in Yantai, a thriving seaport not far from the Bohai Sea. The Yantai plant was to be the beginning of a transition to cleaner coal technology, says Zhao Jie, the plant's designer, now vice president of China Power Engineering. "China wanted to take a cleaner and more efficient way to produce power," says Zhao. Instead, the demonstration plant she designed went on a roller-coaster ride to nowhere. Design work was temporarily halted in 1994 when the cost of the technology was deemed unacceptably high, revived in the late 1990s, and then cut adrift after 2002 by the breakup of the State Power Corporation.

The Yantai power plant was based on integrated gasification combined cycle (IGCC) technology. IGCC plants resemble natural-gas-fired power plants—they use two turbines to capture mechanical and heat energy from expanding combustion gases—but are fueled with syngas from an integrated coal gasification plant. They're not emissions free, but their gas streams are more concentrated, so the sulfurous soot, carbon dioxide, and other pollutants they generate are easier to separate and capture. Of course, once the carbon dioxide—the main greenhouse gas—is captured, engineers still need to find a place to stow it. The most promising strategy is to sequester it deep within saline aquifers and oil reservoirs. In preliminary analyses, Chinese geologists have estimated that aging oil fields and aquifers could absorb more than a trillion tons of carbon dioxide—more than China's coal-fired plants would emit, at their current rate, for hundreds of years.

The Huaneng Group, a power producer based in Beijing, has pulled together a consortium of power and coal interests (Shenhua included) called GreenGen to build the first Chinese IGCC demo plant by 2010; like the related FutureGen project organized by the U.S. Department of Energy, GreenGen is to start with power production, then add carbon capture and storage. China's vice premier, Zeng Peiyan, made an appearance at GreenGen's ceremonial debut last summer, indicating Beijing's support for the project.

The problem is that IGCC plants still cost about 10 percent to 20 percent more per megawatt than pulverized-coal-fired power plants. (And that's without carbon dioxide capture.) China's power producers—much like their counterparts in the United States and Europe—are waiting for a financial or political reason to make the switch. In part, what's been missing is regulation that penalizes conventional coal plants. And China's environmental agencies lack the resources and power to make companies comply even with regulations already on the books. Top officials in Beijing admit that their edicts are widely ignored, as new power plants are erected without environmental assessments and, according to some sources, without required equipment for pollution control.

Even advocates of IGCC technology expect that its widespread deployment in China will take at least another decade. Indeed, Du Minghua, a director for coal chemistry at the Chinese Coal Research Institute, predicts that it will be 2020 before application of IGCC technology begins in earnest.

Waiting to Inhale

Despite such pessimistic predictions, China's vast experience with advanced coal technologies and its proven ability

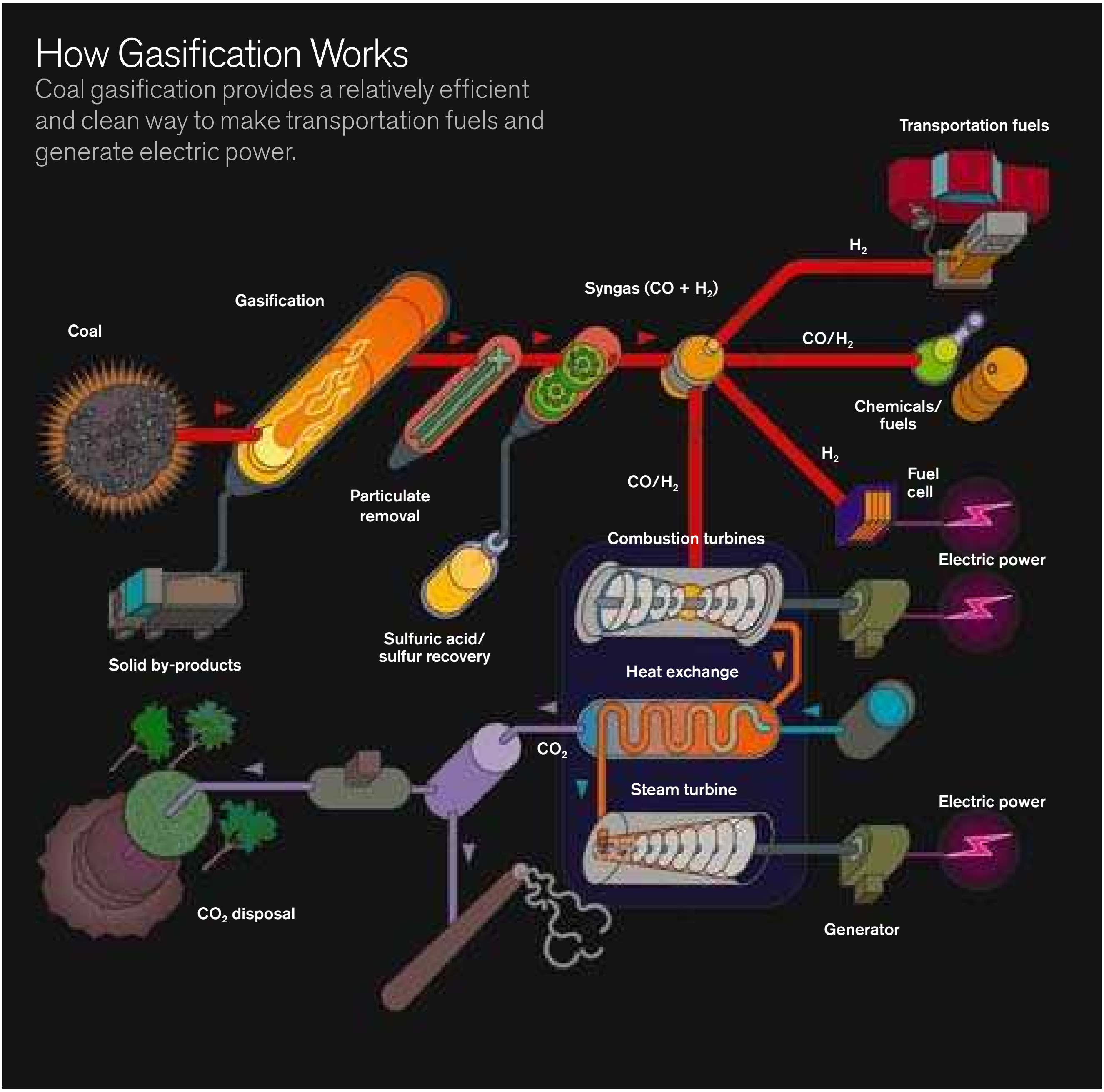


ILLUSTRATION: JEFF WEST; SOURCE: U.S. DEPARTMENT OF ENERGY

to implement new technologies at a startling pace provide ample room for optimism. When you're racing into Shanghai at one-third the speed of sound on a train supported by an electromagnetic force field, it's hard to believe that a country capable of such an engineering feat will continue to ignore the deadly pollution engulfing its cities.

To some analysts, the switch to clean-coal technology seems almost inevitable. "China has to rely on coal for future electricity and fuel needs, and it will eventually have to cap its CO_2 emissions," says Guodong Sun, a technology policy expert at New York's Stony Brook University who has advised the Chinese government on energy policy. "Gasification is one of a very few technologies that can reconcile those conflicting scenarios at reasonable cost."

Still, the timing of such a technology transition is very much in question. Will China really wait until 2020 to start the process of cleaning up its coal-fired power plants? The answer will depend, ultimately, on when China begins to feel that using coal gasification to generate electricity is as urgent as using it to produce transportation fuels—when the costs of air pollution become as worrisome as the costs of relying on foreign oil. TR

Peter Fairley, a Technology Review *contributing writer, traveled to China in October.*

Essay

The Alchemist

A chef in Chicago wants to blow your mind.

By Corby Kummer

When Grant Achatz's French Laundry pals come to visit him in the serene, light-filled kitchen of his Chicago restaurant, Alinea, the scene strikes them as familiar. Why shouldn't it? They all used to work together. For the dozen years since it opened, the French Laundry, in California's Napa Valley, has come in first in most surveys of the country's best restaurants. As an ambitious young chef from a family of unambitious cooks in Michigan, Achatz talked Thomas Keller, the chef-owner of the French Laundry, into giving him a job practically sight unseen, and he ended up as sous-chef–second in command–for two of his four years there. He wanted to be as close as he could to the best. And now, at all of 32, Achatz has just seen *Gourmet* magazine name Alinea the best restaurant in America.

That verdict marks the passing of the torch from the most modern, Americanized version of French haute cuisine to something altogether new. The highest and most expensive forms of cooking have always involved the latest kitchen technology. But seldom has technology worked to bring food as far from what was considered normal as it does today. Cooks are straying into the preserves of the laboratory, appropriating equipment, processes, and ingredients that were formerly of interest only to biology researchers and industrial food manufacturers. Among American chefs, it's Achatz who has most successfully walked the balance beam between weird and appealing–probably because of his rigorous apprenticeship with Keller.

While Achatz was rising at the French Laundry, his head was turned by the newest techniques being practiced in Spain. Keller had arranged for his young cook a four-day visit to the kitchen at El Bulli, considered the international ground zero of culinary innovation, but he and its chef, Ferran Adrià, had very different philosophies. Keller had received classic French training and applied to it his own Germanic, meticulous discipline. His worldview was formed by the nouvelle cuisine revolution of the 1970s and '80s, which opened French cooking to Asian, Indian, and other international influences and replaced flour-thickened sauces with intensely focused butter sauces, often flavored with powerful, cooked-down essences. It's not that he was deaf to the noise coming from Spain: every ambitious chef stays tuned to food news, and Keller certainly ate in Spain. But he had evolved his own style, and it had brought him his own international recognition. Nouvelle cuisine still relied heavily on the battery of equipment handed down from the chefs of the great flowering of haute cuisine, at the turn of the 20th century, and that's what Keller liked. Achatz would convince him to buy the latest gadgets, only to see them sit in a cabinet unused.

So Achatz took a walk on the wild side as the chef of Trio, a restaurant in Evanston, IL, that became both famous and notorious for its novel techniques. After just three years, high-rolling young backers excited by his innovation staked him to Alinea, in the Lincoln Park neighborhood, home to comfortable members of Chicago's intelligentsia. He installed a high-ceilinged kitchen with windows, rare in a city restaurant. The windows may not look out onto an always sunny California garden, like the ones at the French Laundry, but they're nice all the same.

His old friends feel right at home–at first. The terrible quiet, broken only when cooks loudly repeat orders like marine cadets as the woman who receives the slips

MARC BURKHARDT

from the dining room calls them out; the intense concentration; the straight-backed, close-cropped young men huddled around salad plates as if consulting on complicated surgery: all this they know, and when in whites they look and act exactly the same way. But the cool, the literal cool, of the room—it's strange. Four long, mercilessly scrubbed stainless-steel tables are centers of constant activity, with the cooks solemnly shuttling between them and pieces of high-tech equipment on counters along the walls. What's missing is the centerpiece of the French Laundry kitchen—the piece of equipment all its activity revolves around.

After a minute, a visiting cook will ask Achatz, "Where are the stoves?"

Achatz is something new on the national culinary landscape: a chef as ambitious and disciplined as Thomas Keller who wants to make his mark not with perfection but with constant innovation. Where Keller marries ironclad French technique with American ingredients, Achatz plays with every new way to change the viscosity, texture, form, moistness, and even color of food, applying food-industry methods to haute cuisine.

He is not the first cook to aim for Ferran Adrià's nonstop creativity and willingness to try any piece of equipment, industrial thickening agent, or wild idea that might bring about a new sensory nirvana. In France, Marc Veyrat broke ranks with his Michelin-starred colleagues to use many of these techniques at his Maison de Marc Veyrat, near Annecy. In England, Heston Blumenthal made his name, and won three Michelin stars, doing the same thing at the Fat Duck, in the village of Bray, outside London. In Washington, DC, José Andrés, a Spanish-born chef who literally came of age in Adrià's kitchen, runs the purest offshoot of El Bulli at his Minibar. In New York, Wylie Dufresne, at his wd~50, was the first young American chef to spread the Spanish gospel. But the critical mass of cooks is in Chicago, which has become the American Barcelona.

I shouldn't like any of this. I wrote a book on Slow Food, the international movement dedicated to saving farm-raised food and preserving the environment. As the *Atlantic Monthly*'s food writer, I spend most of my professional time talking to cooks who visit farmers, and to farmers who struggle to make a living by raising good food in old, environmentally respectful, deeply uneconomical ways. My own preference is for the simplest food imaginable—the kind intended to pay tribute to the best and most highly flavored ingredients. I regard food innovation with suspicion; I like the names of my ingredients to have one or two syllables, and those names should sound like something from an old map, not from a can of Cheez Whiz.

Even to someone far less retrograde than I, the new high-tech food seems freakish. There are plants, herbs, and body parts you've never heard of and in through-the-looking-glass shapes; you get sugar with the meat, and salt where you don't expect it; and the foams—the notorious foams—come in lurid colors that seem not meant for human consumption. Dishes sound like stunts of publicity-hungry young bloods.

Here's the surprise: get close enough to sit down and allow yourself to be teased, challenged, and coddled by Achatz's version of this kind of cooking, and you can have one of the most enjoyable culinary adventures of your life. Such was my experience when I dined for nearly four hours at Alinea.

You know you're in for something different when you go through the door of Alinea. It leads to a short hallway that looks long because of trompe l'oeil panels that get shorter and narrower, constricting the corridor so that by the time you reach its end, you can't get a good look at the weirdly pulsating wire sculpture you find there without hunching. Just before the hunch point, gunmetal-gray double doors snap open at your side and you enter the gray-and-white dining room—a place of quiet tension and careful repose. The nicely enthusiastic hostess or host (this may be the cutting edge, but it's still the Midwest) seats you at a dark-wood table. The dark wood is part of the strategy; it's meant to signal the food's primacy over any other sensory element. In the multimillion-dollar design process that led to the opening of Alinea, in the spring of 2005, the surroundings were kept spare, so that diners could be at one with their senses.

Fragrance is nearly all in both food and wine, of course, and playing with it, and with textures and temperatures, is an Achatz hallmark. The chef looked for ways to bring the sensuality of smells directly into the dining room. He didn't want to settle for some normal serving dish like, say, the tightly covered cast-iron casseroles that waiters at Jean-Georges Vongerichten's New York City restaurant Jean Georges open under diners' noses. Instead, he bought a bonglike contraption that lets him force scented air into a plastic bag. He gently heats lavender or orange peel or sassafras, captures the aromatized air in the bag, pricks tiny holes in it, and tucks the bag into a specially made linen pillowcase. The waiter sets the pillow under the diner's plate; it slowly deflates as the plate rests on it, scenting the entire place setting.

Odd holders for silverware and crockery, bearing odd ingredients, arrive at odd moments. One night there could be slices of a gnarly "hand" of fresh ginger impaled on spiny stainless-steel needles that look vaguely like a bed of nails; at an unpredictable point a waiter will use a specially designed grater for the ginger, sprinkling the juicy pulp over a soup. Or a chunk of dripping honeycomb will arrive, to be squeezed eventually over a savory course, again using a custom-designed implement. Or you'll be served a square of jelled sweet potato and another of jelled bourbon, both stuck onto a cinnamon-stick skewer that was lightly torched before it left the kitchen, so that it arrives powerfully fragrant.

On the night I dined, as soon as I was seated, a waiter set down a bristling frond of fresh rosemary stuck into a polished stainless-steel holder that looked something like a smart pen stand. It was the only thing by way of a floral arrangement, and it stood sentinel for better than half the 12 courses I tried (this was a beginner's meal: the Alinea menu is divided into a tasting of 12 courses and one of 24). Then a very hot rock arrived—a long terra-cotta brick set on a perilously fragile-looking wire holder. In one end was a deep hole the width of a pencil. The waiter stuck the small branch of rosemary into the hole, and the fragrance engulfed not just me but all the tables around me. In fact, there was barely any rosemary in the three small squares of tender lamb set on the hot brick, each topped with a different condiment: mastic-infused cream (mastic, a Greek resin with a light, bittersweet licorice flavor, is used to thicken ice creams and sweets); mustard-apricot relish with plump, lush dried apricots; and a late-summer marmalade of eggplant and tomato. The meat was tender and succulent, the condiments cannily chosen to set it off without dominating. But it was the rosemary scent mixing with sizzling lamb fat—an almost primeval emotional trigger, the kind Achatz says he wants to pull—that made this the climax of the meal.

I spent several dinner services backstage, observing the kitchen activity behind the sort of dinner I ate. The only fire I saw there—no flaming grills, scant stove activity—was literal: small blazes in a short cylindrical stainless-steel container lined with aluminum foil and stuffed with fallen oak leaves so beautiful it was a shame to burn them. When an order for rabbit (a dish I didn't try) came in, one cook set the leaves afire with a blowtorch, making the kitchen smell like a suburban lawn in the fall. A second cook smothered the fire with the bottom of another steel container covered with foil. A third cook quickly put upside-down old-fashioned glasses over the leaf container, to fill them with smoke. These would serve as cloches for waiting plates of rabbit loin covered with brioche crumbs browned with butter and thyme and set over roasted-garlic butter, accompanied by cider gel thickened with a kind of modified starch used in industrial food processing. Once the glasses were turned right side up, at the table, the waiter would fill them with rabbit consommé. These kitchen and tabletop theatrics gave diners not just the taste of fall but its smoky smell, too.

Semiridiculous as these tricks sound, they exploit the evocative power of scent, memories of which lodge in a primitive storage area in the brain. Scent works: that lamb is the dish I still think about months after I had it. But the meal did not lack for other high points, in which artful visual and olfactory shocks were essential.

Achatz has the eye of a designer. The wire holders are the product of a collaboration with Martin Kastner, a native of the Czech Republic, who crafts metalware and ceramics. One of the pair's most arresting inventions is the "trapeze," which actually looks more like a high wire. It holds swinging slices from a side of bacon that has been frozen so it can be cut paper thin. The slices are dehydrated slowly, so they can be pressed flat and unusually wide; spirals of piped butterscotch and linguine-thin ribbons of dehydrated apple puree wind round their lower halves. The stop-everything presentation, the unusual texture of the bacon (not quite crisp, not quite soft), the way the sweet complements the salty—all are characteristic of Achatz's cooking.

> Then a very hot rock arrived—a long terra-cotta brick set on a perilously fragile-looking wire holder. In one end was a deep hole the width of a pencil. The waiter stuck the small branch of rosemary into the hole, and the fragrance engulfed not just me but all the tables around me.

When you get a plate, it too is designed to subtly disorient. Dinner-sized, elliptical plates at my meal had an incised white-on-white houndstooth design and an almond-shaped smooth center; Achatz patterns them with food like Matisse creating a cutout or Alexander Girard a textile. Lightly seared hamachi

topped with crushed peanuts sits in what looks like a Japanese garden of braised green peanuts, which are delightfully crunchy and slippery, like edamame beans with flavor. Beads of salty buttermilk pudding dot the plate, a bit bigger than the peanuts and a similar cream color, defying gravity to hold their shape. Some sprout delicate sprigs of fresh tarragon; others are topped with three tiny deep-purple blackberries. Polka dots of perfectly behaved berry syrup anchor the design. The plate is more than pretty. Just as the bacon is better than weird—it tastes good—the hamachi is silken, and the pudding, which sounds awful when the waiter describes it, is somehow at one with the fish; the beads have the texture of thick butterscotch pudding and yield to the tongue. (To see how the dish is made, see pages 70 and 71.)

Many things yield unexpectedly in the mouth. That's part of Achatz's experimentation with different thickeners, and with making things solid or liquid depending on what you're not used to. A wide red ribbon marches across a long rectangular dessert plate, for instance, looking like melted plastic. The strangely plastic ribbon is the usually runny raspberry puree, blanketing a series of small dots, all of which have a surprise: tapioca pearls in goat's milk; fresh raspberries stuffed with a chewy little bead of taffy made of fresh red peppers; pistachio brittle and crushed pistachios; and lavender made into a tea that holds its shape like a syrup. Lavender is also dehydrated into tiny chips and crumbled over the length of the ribbon. The whole thing is decorative (its horizontal patterning is reminiscent of a Louis Sullivan or Prairie School design), unexpected, and very good.

How far has this school come from anything recognizably rooted in classic haute cuisine? Will these restless young chefs obliterate everything Slow Food holds dear?

The experiments of the Chicago school can be traced directly to Marie-Antoine Carême (1784–1833), a founder of haute cuisine, who used principles of architectural engineering to create *pièces montées*—fantastic structures, often in the shape of buildings—from modeling ingredients like gum tragacanth. Three generations before Auguste Escoffier codified post-Revolutionary French cuisine, Carême startled diners with beautifully colored and modeled desserts that mysteriously held their form and concealed surprises—surprise being a longtime feature of cuisine for the jaded rich and royal. From its origins in court kitchens of the Renaissance, haute cuisine always used artifice to impress diners with the originality and extravagance of the lord who employed the cook. After the French Revolution, when former cooks to the aristocracy began opening restaurants, they competed to make just as vivid an impression with their own skills, which often had as much to do with novel presentations, equipment, and techniques as with finding the very best ingredients from farmers, fishermen, cheese makers, and other producers. Skill, discipline, and basic understanding of cooking science became necessary for any chef, and to this day apprentice chefs train in the rigorous techniques of classic French cuisine.

Carême also applied to the craft of cooking the Enlightenment idea that a craftsman could become an artist by transforming what nature had made into something original and new. More than 170 years after Carême's death, this ethos finds its most fervent adherents in Adrià and his followers. The most thoughtful of them, like Adrià himself—whom I first took seriously when I encountered him at a number of Slow Food events in Italy—find the best artisan producers and try to intensify and transform the foods they grow and make.

To get a sharper sense of how Achatz and his innovation-bent colleagues depart from the updated classicism of multistarred chefs like Keller and Alain Ducasse, who has restaurants in three countries, I asked Achatz to imagine how several chefs today would approach an haute cuisine warhorse: sole Veronique, folded fillets poached in a vermouth-flavored fish stock and served with a cream-thickened sauce of fish and white wine, garnished with white grapes and puff-pastry crescents. Achatz knew the Keller version by heart, because he was there when Keller reconceived the dish. To sole fillets wrapped around a stuffing made from brioche crumbs, Keller added a cream sauce with white wine, raisins plumped in white wine, and a garnish of two peeled seedless white grapes.

Achatz said that Wylie Dufresne—perhaps the most technical-minded of the young American chefs following Adrià—would probably make a paste of sole mixed with transglutamase, to be extruded into spaghetti-like noodles, and serve it in a classic sauce garnished with grapes: "His manipulation would be the dish." Homaro Cantu, of the Chicago restaurant Moto—perhaps the most direct disciple of Carême in the current group—would first give the diner a picture of sole Veronique on a piece of paper that was meant to be eaten (as are a lot of his menus; he uses an ink-jet printer to spray edible inks of his own devising onto paper made of soybeans and cornstarch). Then he would set before the diner a patented superinsulating polymer box preheated to

"WHERE ARE THE STOVES?" The kitchen at Alinea, dinnertime. Chef Grant Achatz is at center, in whites.

LARA KASTNER

350 °F. A waiter would remove the lid to reveal a top layer of carbonated grape, made by putting whole fruits into a carbonation canister; the waiter would take away that layer and reveal steamed sole that had been cooking at the table. For the last course, the waiter would pour the fish-steaming broth into a bowl. Playing with the image and deconstructing the dish would be the Cantu hallmarks.

Achatz himself would concentrate on scent and texture, poaching the fish in a tepid water bath in a vacuum-sealed plastic bag—the "sous vide" process many chefs now swear by to give meat, fish, and some vegetables a creamy consistency. He would put grape juice into the bag with the fish, to infuse the essence of its flavor into the flesh. Then he would capture the aromas of classic fish sauce—vermouth, tarragon, fish stock—either in an aromatic pillow or in a vapor sprayed around the diner when the fish was served. He might use an industrial thickener to make a kind of fruit gum of cooked-down white-grape juice, to alter the texture and intensify the flavor of the grapes. Three approaches meant to make the diner think about flavor and the whole experience of dining in a new way.

And, however first-rate the ingredients, three approaches designed to draw attention to the bravura and originality of the chef. This is where the new approach diverges from Slow Food, where the author is Nature. Achatz's own divergence from the American nouvelle cuisine of his mentor marks an interesting irony: his aggressive use of technology is often in the service, as is Keller's use of classical technique, of great emotion—the odd techniques and sheer novelty are only its most obvious manifestations. The cool bloodlessness of his kitchen—and, it must be said, of the chef himself: tall, lean, and pensive, with red hair, finely etched features, and freckles that underscore his youth—produces food meant to celebrate and open up the realm of the senses.

Executive chefs usually take a hand in actual preparations only when they see a cook put something awry. That approach would be understandable in a restaurant with 16 cooks and dinners that regularly feature two dozen courses. But on the nights when I visited the Alinea kitchen, Achatz took an active role, preparing each plate of "shellfish sponge"—a dish with what looked like a soft white meringue cloud in the center, garnished with thin, horizontally sliced mussels and clams. Watching Achatz choose each delicate shellfish slice and spoon out celery granité and two kinds of sauce was like watching a surgeon—an effect heightened by his somber mien, the immaculate white cutting boards, and the C-fold white paper towels set before the plates like surgical napkins.

When I ate the sponge at table, I had no idea what to expect. Atop the cloud was the granité, and around it were Creamsicle-orange gooseberry sauce and horseradish cream the consistency of crème fraîche. I was startled by the brisk, cleansing seafood flavor and the soft, foamy texture of the sponge against the fine tingle of the granité and the luxuriant, delicately hot cream. The dish was a triumph of finesse.

Achatz told me that this dish neatly and specifically illustrated the difference between him and Keller. Steaming the shellfish in a broth based on vermouth and aromatic vegetables including fennel, he said, was "straight out of the French Laundry playbook," as are eight out of ten of the ways he "extracts flavor." But rather than use the broth for a billi-bi, a creamy French mussel soup, or a tomato-based, saffron-seasoned Provençal stew, he strains the broth and adds Ultra-Tex 3 (a modified tapioca starch that thickens without being heated), whips it into a mousse that looks exactly like mounted egg whites, and then chills it to set like a Bavarian cream. The flavoring accompaniments (with the exception of the fairly extraneous gooseberry) are relatively standard, but the textures are not.

Achatz dates his great leap forward to 2003, when he was cooking at Trio. He decided to check out the convention of the Institute of Food Technology, a group that serves companies like Kraft (the food industry has always loomed large in Chicago).

Achatz dates his great leap forward to 2003, when he was cooking at Trio. He decided to check out the convention of the Institute of Food Technology, a group that serves companies like Kraft (the food industry has always loomed large in Chicago: Kraft, Sara Lee, and McDonald's are all nearby). He and a fellow Trio cook watched, rapt, as someone poured a liquid over a steel tray, sprayed some kind of mist on it, and then encapsulated spoonfuls of it like so many freestanding egg yolks. (At Minibar, in Washington, José Andrés encapsulates the dressing for a deconstructed Caesar salad; the result looks like an egg yolk but spurts dressing when pierced.) The liquid, they learned, had contained sodium alginate, and the mist was of calcium chloride. Achatz took away a one-pound sample of the sodium alginate.

Soon after, he read about a pea ravioli encapsulation in a magazine story about Adrià. It reminded him of his own "truffle explosion"—a truffle broth thickened with old-fashioned gelatin and chilled solid enough to serve as a filling for ravioli. When simmered, the filling melted; it spurted into diners' mouths. The push to evolve the idea behind the dish (the alginate-calcium combination would be used for all manner of tricks, such as an alarming rush of hot beet juice from an innocent-seeming icy white lemon-thyme foam) was typical Achatz: the discovery and research, the time spent browsing technical websites and speaking with representatives of additive makers unused to customers who want to order in one-pound, not fifty-pound, quantities.

Truffle explosion was a Trio signature, though in his restless way Achatz soon left it behind. My visit to Alinea fell near the anniversary of its opening, a week in which Achatz brought back some of his greatest hits; I asked him to make the ravioli. The effect was interesting enough, but the salty broth and the pasta casing were lukewarm, with cold, hard grated Parmigiano-Reggiano on top. The temperatures didn't seem intentional, showing that the execution must be flawless for many of Achatz's effects to come off.

Achatz likes "thermal reversal," as he calls the exploding-ravioli effect. He uses it for the raspberry ribbon, freezing a sheet of boiled-down, thickened raspberry puree and syrup raked to a perfect 16th of an inch; cooks cut the sheet into ruler-straight ribbons to lay across the flavored dots placed along rectangular plates, and then partially melt the ribbon with a blowtorch, just before it is served, to create the molten-plastic effect. Broken slabs of dark Venezuelan Ocamari chocolate wait beneath a lamp all evening, heated to 94 °F, until they are transferred to a dessert plate with dehydrated chocolate pudding, cassia mousse, and figs braised with port; the shards just hold their shape but melt in the mouth like s'mores.

These dishes require low-tech methods to achieve the desired results, and Achatz can even find use for low-tech thickeners like plain gelatin and the lab staple agar (for those pert beads of buttermilk pudding). But my own favorite use of a gelling agent was the mixture of caramel and sodium maltodextrine, which absorbs fat rather than water, the way cornstarch and most other thickeners do. The caramel flakes look something like white-chocolate nut clusters and re-form as chewy dime-store vanilla caramel in the mouth. It's a gee-whiz moment that's plain fun.

Fun is something Achatz wants diners to have, along with the occasional scare (those acupuncture-reminiscent needles). But some of his ideas don't go

over. He once bought black atomizers and filled them with essence of shrimp cocktail, made by pushing shrimp shells, stock, tomatoes, horseradish, and vinegar through a countertop wine press. Waiters sprayed the atomized essence into diners' mouths. The effect was uncanny, but it provoked an outcry. Critics said Achatz wanted to divorce diners from actual food. Among other things, he says, he was accused of wanting to change the molecular structure of food and feed the world with essences. Achatz, not an especially whimsical fellow himself, wanted to tell critics to lighten up: none of the accusations were true. But he nevertheless threw out the atomizers.

Many gadgets have wound up in the crawl space behind the kitchen. Even the vacuum-packing machine that is now a staple of ambitious restaurants across the land is kept in a low, closed cabinet, though on any night a few meats will have been cooked in vacuum-packed bags, which give meat and fish a satiny texture and focused flavor. The infamous soda siphon also comes out seldom. Achatz thinks foams have gotten a bad rap, defending them as a "legitimate saucing technique" that allows chefs to aerate ingredients without having to dilute the flavor of, say, chocolate with the beaten egg whites and whipped cream that go into a mousse: "Come on, it has its uses." But foams are usually just supporting players, not the stars, in his kitchen. He'll make a tomato-water foam, for instance, but hide it. Curtis Duffy, his longtime chef de cuisine, will form to order small balls of fresh mozzarella, kneading a wad of curd he keeps warm and pliable all night over a freestanding electric burner with an LED temperature readout. Just before he seals the ball, he sprays in some of the tomato foam, as a filling. The cold foam unexpectedly comes out of the mozzarella, like thermal-reversed chicken Kiev.

Atomizers aren't the only Alinea gadgets to have gone away altogether. A lab-scale centrifuge went on eBay after Achatz and his chefs had too much trouble realizing his dream of a "self-encapsulating" liquid that would freeze as a hollow sphere, into which he would inject liquid—a sort of popsicle with a juicy center. A stick homogenizer, usually found in cosmetics factories, well and truly emulsified vinaigrette—but not so memorably that Achatz was convinced to replace the professional-strength juicer he and other chefs rely on to make purees. A paint sprayer he intended to use to "shellac" liquid chocolate with curry-infused cocoa butter was a hassle, and noisy. He liked carbonating grapes, putting the fruit right into a carbonation canister; but his rival Homaro Cantu was already carbonating fruits, and he didn't want to look like a copycat.

But technology remains Achatz's signature interest. Besides visiting trade shows and continually surfing the Web, he has formed collaborations with machine designers, as he did with Kastner—and, as with Kastner, the collaborations have resulted in products that go on sale. One example is a bread-box-size machine with a flat square surface that flash freezes anything on it. Other chefs use liquid nitrogen for flash freezing, but that struck Achatz as "too science-y, too sterile." He proposed to PolyScience, a nearby equipment maker that produces the "immersion circulators" he uses to cook vacuum-packed food, that they make him a surface for flash freezing. He calls it the antigriddle.

Achatz and his Chicago contemporaries have not just placed themselves at the front ranks of the avant garde; they are the future of American cooking, in a self-conscious but valid way. Just as he has built on what he learned, proclaiming his roots in Keller's teachings, Achatz knows that the 22-year-olds in his kitchen will one day have kitchens of their own and come up with the next cuisine. Many of them came to him through his frequent postings on eGullet.com, a website for chefs and foodies, where during the run-up to the opening of Alinea he kept a blog. His kitchen is already a self-selecting school, and his students will go on to grow without and perhaps beyond him.

On my last visit to the kitchen, I met a wide-eyed and extremely ambitious cook, all of 19 years old, named Chad Kubanoff, who had read some of Achatz's eGullet postings and started pelting him with e-mailed requests for a job. He had snagged an entry-level job at Daniel, a temple of nouvelle-classic cuisine in New York, when Daniel Boulud himself, a chef as revered as Keller and as gold-plated a meal ticket for aspiring chefs, came to teach a class at the Culinary Institute of America and was impressed by the beginning student who assisted him. But the very young man ditched it to move to Chicago for the chance just to "stage" (the French term for apprenticing) in the Alinea kitchen. Why did he take the risk? To try out new gadgets like the antigriddle, where he was freezing little chestnut lozenges the night I spoke with him. "I wanted to do something new, stuff that hasn't been done before," he told me. Had he seen anything like what surrounded us in the Alinea kitchen when he was studying at the Culinary Institute of America, the country's preëminent training institution for chefs? He laughed scornfully. "Nothing." TR

Corby Kummer is a senior editor at the Atlantic Monthly, *for which he writes a regular column on food.*

Chef Grant Achatz's Hamachi: Don't Try This at Home

Diners at Achatz's Chicago restaurant, Alinea, choose between a 12- and a 24-course menu. Each dish holds a surprise brought off by methods more typical of laboratories than kitchens.

1

In an old-fashioned bar blender, fresh blackberries imported from Chile are blended for a vinaigrette of red-wine vinegar, grapeseed oil, salt, sugar, and a liqueur made from cassis—dramatically big and deep-flavored blackberries popular in France.

2

After the blackberry sauce is pressed through a traditional conical, fine-mesh sieve called a chinois, it is blended with Ultra-Tex 3, a thickener generally used in the food industry, and one Achatz likes because it requires no heating.

3

The cassis vinaigrette will be one of two sauces used to both decorate the serving plate and complement the flavor of the lightly cooked hamachi fillets. (Squeeze bottles and plastic deli containers are standard restaurant-kitchen equipment.)

4

Agar agar, the seaweed-based gelling agent found in every biology lab, is used to thicken a buttermilk pudding. Agar thickens to a very firm consistency; the amount of Ultra-Tex needed to produce the same thickness would make the texture of the pudding gummy.

5

The pudding does not have eggs, as standard puddings do; the agar does the thickening. Achatz simmers heavy cream with pre-weighed agar and, using an immersion blender, slowly adds cool buttermilk, which can separate over direct heat.

6

One reason Alinea is very expensive: the immense amount of labor required to achieve nearly every dish. Here, familiar blackberries are meticulously pulled apart, bead by bead, to make miniature berries that will carpet the plate.

LARA KASTNER

7

One of America's great regional treats, known to every Southerner, is boiled peanuts—slippery and crunchy like Japanese edamame beans and fun to eat. Here they have been shelled and skinned and set to simmer until tender but crunchy.

8

Achatz buys whole hamachi from a premium sushi-fish vendor in San Mateo, CA, and cuts them at Alinea, separating the top loins from the bellies; for the hamachi dish described here, he uses the top loin.

9

A popular current restaurant trick is to give fish fillets a crisp "skin" made from something else (Spaniards are using new comestible glues to fuse chicken skin to fish). Achatz hasn't gone quite that far yet, but he likes the idea.

10

Instead, he blends ground toasted peanuts, peanut oil, and butter into a paste or "panade," cut to form a crunchy cover. Using one of the kitchen's few old-fashioned sources of direct heat, he browns the panade under a "salamander," or broiler.

11

Achatz himself dots plates with beads of buttermilk pudding and blanched peanuts, which look almost the same, and with blackberry beads; then he drizzles on blackberry sauce and randomly places sprigs of tarragon in pudding beads to make a textile-patterned bed for the hamachi.

12

Reviews

Books, artifacts, reports, products, objects

SOFTWARE

Uninspiring Vista

How Microsoft's long-awaited operating system disappointed a stubborn fan. By Erika Jonietz

For most of the last two decades, I have been a Microsoft apologist. I mean, not merely a contented user of the company's operating systems and software, not just a fan, but a champion. I have insisted that MS-DOS wasn't hard to use (once you got used to it), that Windows 3.1 was the greatest innovation in desktop operating systems, that Word was in fact superior to WordPerfect, and that Windows XP was, quite simply, "it."

When I was forced to use Apple's Mac OS (versions 7.6 through 9.2) for a series of jobs, I grumbled, griped, and insisted that Windows was better. Even as I slowly acclimated at work, I bought only Windows PCs for myself and avoided my roommate's recherché new iBook as if it were fugu. I admitted it was pretty, but I just knew that you got more computing power for your buck from an Intel-based Windows machine, and of course there was far more software available for PCs. Yet my adoration wasn't entirely logical; I knew from experience, for example, that Mac crashes were easier to recover from than the infamous Blue Screen of Death. At the heart of it all, I was simply more used to Windows. Even when I finally bought a Mac three years ago, it was solely to meet the computing requirements of some of the publications I worked with. I turned it on only when I had to, sticking to my Windows computer for everyday tasks.

WINDOWS VISTA OPERATING SYSTEM
$99.95–$399.00
www.microsoft.com/windowsvista

So you might think I would be predisposed to love Vista, Microsoft's newest version of Windows, which was scheduled to be released to consumers at the end of January. And indeed, I leaped at the opportunity to review it. I couldn't wait to finally see and use the long-delayed operating system that I had been reading and writing about for more than three years. Regardless of widespread skepticism, I was confident that Vista would dazzle me, and I looked forward to saying so in print.

Ironically, playing around with Vista for more than a month has done what years of experience and exhortations from Mac-loving friends could not: it has converted me into a Mac fan.

A little context and a caveat: in order to meet print deadlines, I had to review the "RC1" version of Vista Ultimate, which Microsoft released in order to gather feedback from over-eager early adopters. Such post-beta, prerelease testing reveals bugs and deficits that in-house testing misses; debuggers cannot mimic all the various configurations of hardware, software, and peripherals that users will assemble. And Vista RC1 was maddeningly buggy. Although I reminded myself repeatedly that most of the problems I encountered would be fixed in the final version, my opinions about Vista are probably colored by my frustrations.

Still, my very first impression of Vista was positive. Quite simply, it's beautiful. The Aero visual interface provides some cool effects, such as translucent window borders and a way to scroll through a 3-D "stack" of your open windows to find the one you want. Networking computers is virtually automatic, as it was supposed to be but never quite has been with Windows XP. The Photo Gallery is the best built-in organizer I've used to manage digital pictures; it even includes basic photo correction tools.

But many of Vista's "new" features seemed terribly familiar to me—as they will to any user of Apple's OS X Tiger operating system. Live thumbnails that display petite versions of minimized windows, search boxes integrated into every Explorer window, and especially the Sidebar—which contains "Gadgets" such as a weather updater and a headline reader—all mimic OS X features introduced in 2005. The Windows versions are outstanding—they're just not really innovative.

Unfortunately, Vista RC1 contained bugs that rendered some promising features, such as the new version of Windows Media Center, unusable for me (an acquaintance who acquired a final copy of Vista ahead of release assures me that all that has been fixed).

My efforts to get Media Center working highlighted two big problems with Vista. First, it's a memory

Vista's Aero visual environment includes the Flip 3-D feature, which allows a user to cycle through a stack of open windows to find the desired application (top), and translucent window borders (bottom). Vista also offers "Gadgets," small programs that recall Mac "Widgets" (far right of screen).

hog. The hundreds of new features jammed into it have made it a prime example of software bloat, perhaps the quintessence of programmer Niklaus Wirth's law that software gets slower faster than hardware gets faster (for more on the problems with software design that lead to bloat, see "Anything You Can Do, I Can Do Meta," p. 36). Although my computer meets the minimum requirements of a "Vista Premium Ready PC," with one gigabyte of RAM, I could run only a few simple programs, such as a Web browser and word processor, without running out of memory. I couldn't even watch a movie: Windows Media Player could read the contents of the DVD, but there wasn't enough memory to actually play it. In short, you need a hell of a computer just to run this OS.

Second, users choosing to install the 64-bit version of Vista on computers they already own will have a hard time finding drivers, the software needed to control hardware subsystems and peripherals such as video cards, modems, or printers. Microsoft's Windows Vista Upgrade Advisor program, which I ran before installing Vista, assured me that my laptop was fully compatible with the 64-bit version. But once I installed it, my speakers would not work. It seems that none of the companies concerned had written a driver for my sound card; it took more than 10 hours of effort to find a workaround. Nor do drivers exist for my modem, printer, or several other things I rely on. For some of the newer components, like the modem, manufacturers will probably have released 64-bit drivers by the time this review appears. But companies have no incentive to write complicated new drivers for older peripherals like my printer. And because rules written into the 64-bit version of Vista limit the installation of some independently written drivers, users will be virtually forced to buy new peripherals if they want to run it.

Struggling to get my computer to do the most basic things reminded me forcefully of similar battles with previous versions of Windows—for instance, the time an MIT electrical engineer had to help me figure out how to get my computer to display anything on my monitor after I upgraded to Windows 98. Playing with OS X Tiger in order to make accurate comparisons for this review, I had a personal epiphany: Windows is complicated. Macs are simple.

This may seem extraordinarily obvious; after all, Apple has built an entire advertising campaign around the concept. But I am obstinate, and I have loved Windows for a long time. Now, however, simplicity is increasingly important to me. I just want things to work, and with my Mac, they do. Though my Mac barely exceeds the processor and memory requirements for OS X Tiger, every bundled program runs perfectly. The five-year-old printer that doesn't work at all with Vista performs beautifully with OS X, not because the manufacturer bothered to write a new Mac driver for my aging standby, but because Apple included a third-party, open-source driver designed to support older printers in Tiger. Instead of facing the planned obsolescence of my printer, I can stick with it as long as I like.

And my deepest-seated reasons for preferring Windows PCs—more computing power for the money and greater software availability—have evaporated in the last year. Apple's decision to use the same Intel chips found in Windows machines has changed everything. Users can now run OS X and Windows on the same computer; with third-party software such as Parallels Desktop, you don't even need to reboot to switch back and forth. The chip swap also makes it possible to compare prices directly. I recently used the Apple and Dell websites to price comparable desktops and laptops; they were $100 apart or less in each case. The difference is that Apple doesn't offer any lower-end processors, so its cheapest computers cost quite a bit more than the least-expensive PCs. As Vista penetrates the market, however, the slower processors are likely to become obsolete—minimizing any cost differences between PCs and Macs.

I may need Windows for a long time to come; many electronic gadgets such as PDAs and MP3 players can only be synched with a computer running Windows, and some software is still not available for Macs. But the long-predicted migration of software from the desktop to the Internet is finally happening. Organizations now routinely access crucial programs from commercial Web servers, and consumers use Google's services to compose, edit, and store their e-mail, calendars, and even documents and spreadsheets *(see "Homo Conexus," July/August 2006)*. As this shift accelerates, finding software that works with a particular operating system will be less of a concern. People will be able to base decisions about which OS to use strictly on merit, and on personal preference. For me, if the choice is between struggling to configure every feature and being able to boot up and get to work, at long last I choose the Mac. TR

Erika Jonietz is a Technology Review *senior editor.*

CONSUMER ELECTRONICS

Tech's Libris

Sony's e-book reading device is the most ingenious to date. It may fail anyway. By Wade Roush

In 2006, Sony tested the patience of e-book fans by twice delaying the release of its PRS-500 reading device, originally set for the spring. The company finally started taking orders over the Web in September, and the gadget can now be bought at electronics stores and some Borders bookstores.

It was worth the wait. The Sony Reader's selling point is its black-and-white "electronic paper" screen, which has been advertised as a far better imitation of ink on paper than the LCDs found in laptops, cell phones, and earlier generations of e-book reading devices. After curling up for a couple of weeks with a unit lent to me by Sony, I'm happy to report that it lives up to its billing. It isn't a replacement for paper—but it is the first e-book device that works well enough to appeal to a large swath of readers, even given its $350 price tag.

SONY READER (PRS-500)
$349.99
www.sony.com/reader

If electronic publishing is to take off, a good reading device will be necessary but not sufficient. Sony's system for delivering e-books has a key weakness: content is too expensive. At the prices Sony and its publishing partners are charging for the e-book versions of current hardcovers, just 25 books will set you back about $350. The same problem has derailed almost every attempt at making electronic books into a mass-market product.

I'd been waiting for Sony to release an English-language e-book reader since 2004, when it introduced its first e-paper device, the Librié, in Japan. My interest in electronic-paper technology dates back to 1999–2001, when I served as managing editor for a technology news site called eBookNet. The site was owned by a startup called NuvoMedia, which manufactured the Rocket eBook, an elegant little device that captured my fancy when I first reviewed it—for *Technology Review*—in 1999. NuvoMedia is now defunct, the victim of high e-book prices imposed by publishers and an ill-conceived merger with Gemstar–TV Guide International. Most of its competitors went down, too. Sony was one of the first to reënter the market.

Even in my NuvoMedia days, I was aware of the technology being developed by E Ink, a startup in Cambridge, MA, founded in 1997 by researchers at MIT's Media Lab *(see "Electronic Paper Turns the Page," March 2001)*. Their clever idea: sandwich millions of tiny, liquid-filled microcapsules between two layers of electrodes, the top one transparent. Floating inside each microcapsule are thousands of positively charged white particles and negatively charged black particles. A negative charge applied at a given electrode on the lower layer pulls the white particles to the bottom of nearby microcapsules and pushes the black particles to the top, creating a black mark beneath the transparent electrode; clusters of these marks make up the equivalent of a black pixel in an LCD screen. This held out the promise of both higher resolution (since the pixels can be made smaller than those in LCDs) and longer battery life (since the particles stay in place, without any further electricity use, until the user calls up the next page). And this is the technology that Sony licensed for the Librié and the Reader PRS-500.

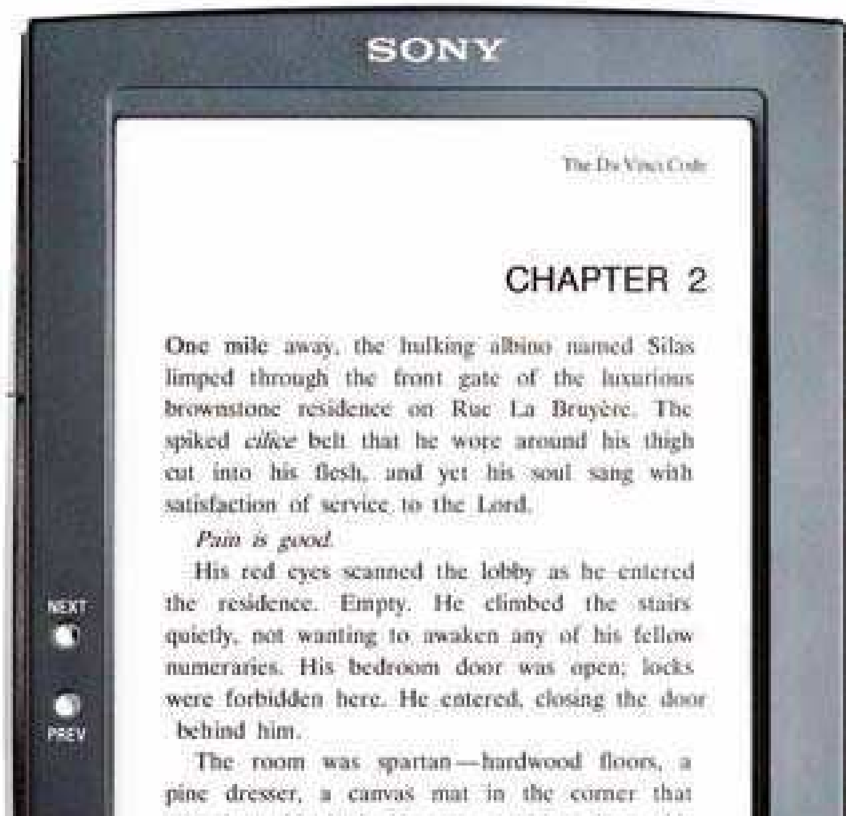
I'd long wanted to see E Ink's technology in action. And as it turns out, the Reader's six-inch-diagonal display is a beauty. It's 800 pixels high

and 600 pixels wide, giving it a resolution of roughly 170 pixels per inch (that trounces a standard LCD's 90 to 120 pixels per inch), which means characters appear sharper and smoother than on other displays. The Reader's screen doesn't achieve the crispness of black text on the thick, bleached pages of a hardcover book. But the contrast ratio of the Reader's screen—the brightness of the whites measured against the deepness of the blacks—is 8:1, which puts it on a par with newsprint.

Sony was careful to make the quarter-kilogram device, which weighs about as much as a two-thirds-full can of soda, comfortable to hold and easy to operate. There are special buttons for navigating from any page in an e-book to the table of contents and to various chapters; there's another button for changing the text size, a helpful feature for the bifocals crowd. The device lacks a search function, but you can skip through a book in 10 percent (or 10-page) increments, and there's a bookmark button.

The only two buttons you have to remember, though, are the ones for paging forward and back. And you can press those buttons up to 7,500 times before the Reader runs out of power, according to Sony. I believe it. I charged the device once, used it for more than 20 hours, and never came close to depleting its battery.

But if you buy a lot of e-books from Sony's online bookstore, you will quickly deplete your wallet. The "Connect eBooks" store is to the Reader what iTunes is to the iPod and is almost as easy to use; customers browse titles using a Windows program provided with the Reader, download purchased e-books to their PCs, and manually synchronize their Readers with their PCs. The store offers a decent range of current and backlist titles, at prices comparable to those Amazon charges for print books. For example, the electronic version of Walter Mosley's *Fortunate Son*, which lists at $23.95 in hardcover, is discounted by the publisher to $17.95, and further discounted by Sony to $14.36. (Amazon charges $16.29 for the hardcover.) But I can't see readers paying that much for e-books. A $5.95 paperback, cheap as it may feel, is a concrete thing.



COURTESY OF SONY

In fact, I doubt that e-books will be seen as a viable alternative to commercial print books until they're so cheap that their ephemerality doesn't matter to buyers. With iTunes, Apple has demonstrated that for downloadable songs and TV shows, this magic price point is $1 to $2. Because reading an e-book is so different from reading a print book, e-books aren't directly comparable to downloadable songs, which can sound just as good as CDs. Still, I'd guess the magic price point is quite low; personally, I wouldn't pay much more than $5 or $6, or about the price of a low-end paperback.

Of course, high book prices aren't the only reason the Sony Reader may be slow to catch on. Many people's pockets and purses are already stuffed with more gadgets than they'd like. A dedicated e-book reader may not make the cut. And while Sony's device is capable of displaying Word files, PDFs, gray-scale graphics, and RSS feeds (including news stories or blog entries downloaded each day from the Web), it doesn't do any of these things as well as laptops do.

Still, when it comes to pure readability, the Sony Reader proves that e-book technology is finally good enough to appeal to parts of the mass market. In fact, it may be just the first of a new generation of reading devices: in November, iRex, a Dutch spinoff of Royal Philips Electronics, started shipping the iLiad e-paper device (which looks remarkably similar to the Sony Reader but costs more than twice as much), and rumors in the blogosphere indicated that Amazon was working on its own e-paper device. Now hardware makers and content providers need to settle on a business model that makes sense to consumers. Economics, not ergonomics or engineering, will determine whether the second coming of e-book devices lasts longer than the first. TR

Wade Roush is a Technology Review *contributing editor.*

ENVIRONMENTAL REGULATION

Remembering the Montreal Protocol

As its 20th anniversary approaches, what can the landmark agreement on controlling CFCs teach those who want to control greenhouse gases? **By David Rotman**

Until the early 1970s, it could be said that, like politics, all chemistry was local. That changed in dramatic fashion with a series of discoveries concerning the global effects of a family of chemicals called chlorofluorocarbons, or CFCs. These compounds had played a key role in the midcentury chemical revolution, allowing such innovations as safe refrigeration, cheap aerosol deodorants, and widespread air conditioning. First commercialized by DuPont in the early 1930s under the trade name Freon, CFCs appeared to be the perfect industrial chemical: nontoxic, nonflammable, and odorless. But in 1973, a pair of chemists at the University of California, Irvine—Sherwood Rowland and his postdoctoral fellow Mario Molina—began to explore the fate of the CFC gases that were being emitted into the atmosphere. Molina began the investigation of CFCs in October of that year, and by Christmas, the researchers had their answer: the CFCs were breaking down in the atmospheric ozone layer, which begins 15 kilometers above the earth, ends roughly 30 kilometers later, and absorbs much of the sun's deadly ultraviolet radiation.

The researchers found that the CFCs wafted up through the lower atmosphere intact, too stable to react with the swirling brew of chemicals around them. But once they reached the mid-stratosphere, above most of the protective layer of ozone, the intense solar radiation broke the CFC molecules apart, releasing chlorine. Two simple reactions gave Rowland and Molina concern: $Cl + O_3 = ClO + O_2$, and $ClO + O = Cl + O_2$. That is, chlorine (Cl) reacted with ozone (O_3), generating chlorine monoxide (ClO), which in turn reacted with an oxygen atom to release another chlorine; the net result was that the chlorine was destroying ozone without depleting itself. "When we found the chain reactions" occurring in the ozone layer, remembered Rowland this fall, the fate of CFCs "suddenly went from a scientific curiosity to an environmental worry."

THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER
September 16, 1987

The next decade was a contentious one for Rowland and Molina, as many in the general public, the chemical industry, and even the scientific community expressed skepticism that a nontoxic gas sprayed out of a can (in the early 1970s, recalls Rowland, roughly two-thirds of CFCs were used as propellants in aerosol products, such as deodorants) could have a significant impact on the composition of the atmosphere—much less on the viability of life on earth. "If you came off the street, it seemed ludicrous that underarm deodorants might have an effect in a global way," Rowland says.

In 1978 the United States banned the use of CFCs in most spray-can applications. But in the early 1980s, models of the atmospheric chemistry involving CFCs became more and more complex, and various questions arose over the science.

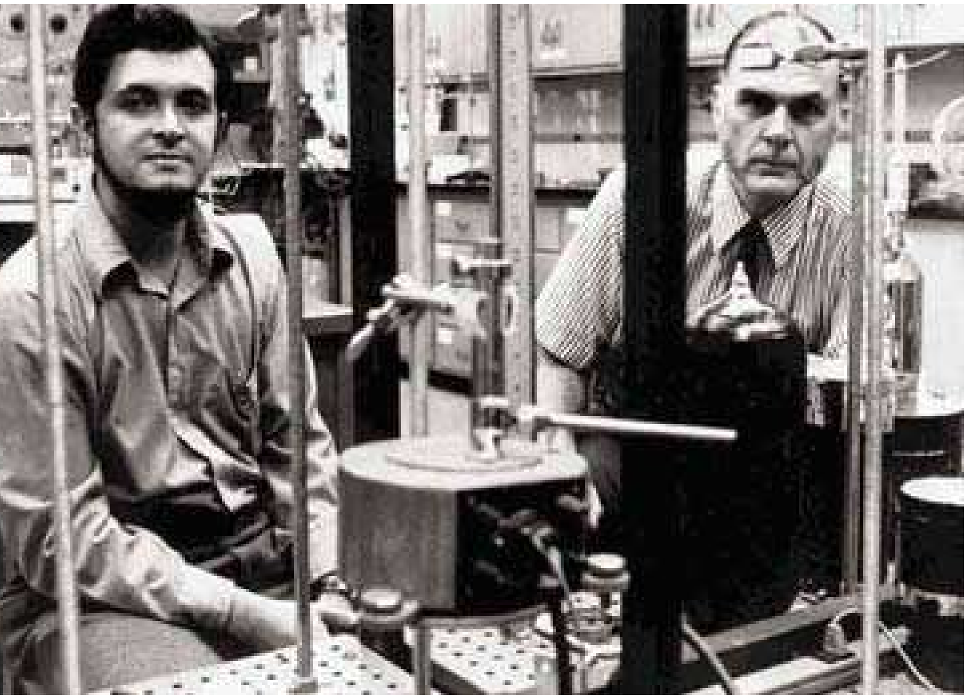
In 1985, Rowland and Molina were vindicated. British scientists using ground-based instruments spotted a gaping "hole" in the ozone layer above the Antarctic. Subsequently, NASA reported that there was a thinning of the ozone layer over the populated areas of the Northern Hemisphere. These findings proved that Rowland and Molina's chemistry had been correct. They also provided startling evidence that industrial chemicals, emitted largely over the industrialized population centers of North America and Europe, could change the atmosphere on a global scale.

Ozone Diplomacy

This September will mark the 20th anniversary of the Montreal Protocol on Substances that Deplete the Ozone Layer, an international agreement that set a schedule for freezing and then phasing out the production of CFCs (the 1987 treaty, which mandated halving CFC production in industrial countries by 1998, was subsequently revised; CFC production was ended in the United States by 1996). The Montreal Protocol is widely considered a milestone. Even President Reagan, no friend of environmental regulations, declared it a "monumental achievement" as he signed the treaty.

Two decades later, progress toward an international agreement on controlling greenhouse gases has reached a deadlock, and comparisons are inevitable. There are, of course, differences between CFCs and the gases, including carbon dioxide, that cause global warming. Most important, the energy production that releases carbon dioxide drives the economies of both rich and poor countries. What's more, whereas CFCs were produced by a handful of large chemical companies, carbon dioxide emissions involve many different industries and applications. Curbing greenhouse gases will be far harder and require changes that are far more economically disruptive.

But there are also striking similarities between CFCs and greenhouse gases, and lessons to be learned from



ASSOCIATED PRESS

Chemists Mario Molina (left) and Sherwood Rowland, shown in 1976, calculated that CFCs used in aerosols, refrigeration, and air conditioning were destroying the ozone layer.

the Montreal Protocol—particularly how to get multiple countries, large international corporations, and regulators to agree on a control strategy. In his 1991 book, *Ozone Diplomacy*, Richard E. Benedick, deputy assistant secretary of state for environment, health, and natural resources under President Reagan, described the compromises that led to the success of the Montreal Protocol, detailing the scientific and technological uncertainties and the political disputes that faced those negotiating it. He points out that many elements of his story, particularly the political fighting and the need to reach a consensus in the face of doubt, should be familiar to those attempting to reach an agreement on greenhouse gases. As Benedick, the chief U.S. negotiator on the Montreal Protocol, writes in the 1998 revised edition, "Especially to apologists of inaction on the climate front, the Montreal Protocol can be portrayed as either too simple or not replicable. But although it is obvious that the climate change issue is more complicated and difficult than that of the ozone layer, the differences are quantitative rather than qualitative."

Indeed, in one important respect the effort to reduce greenhouse gases is fundamentally like the effort to reduce CFCs: in each case, those who want change must motivate industry, especially large corporations, to develop the technologies needed to accomplish it. One of the most notable achievements of the Montreal Protocol was that chemical companies quickly saw the market opportunities created by the agreement. By its account, DuPont, the Wilmington, DE–based chemical giant that in the mid-1980s made roughly half the CFCs produced in the United States, spent $500 million over the next few years to develop substitutes. By the early 1990s, DuPont and its industry rivals, which included some of the world's largest chemical manufacturers, had begun to supply CFC substitutes to refrigeration and air-conditioning manufacturers, and they'd launched massive construction projects to build additional capacity to produce these chemicals.

Again, the differences between CFCs and greenhouse gases are notable; the new compounds could, more or less, directly replace CFCs, but there are no easy substitutes for burning fossil fuels. Nevertheless, the phaseout of CFCs highlights one factor that's crucial in order for industry to invest in the development of new technologies. By announcing a simple and unambiguous time frame for the end of CFC production, the Montreal Protocol allowed companies to rationally predict and develop markets for alternatives.

A Stern Warning

Can such simplicity be duplicated in an international agreement to control greenhouse gases? Probably not, given the complexity of the task and the great diversity of industries and technologies that need to be part of the solution. But neither should the history of the Montreal Protocol be ignored.

DuPont and the other CFC producers were ultimately motivated by the prospect of a lucrative new market; given such an incentive, their chemists and chemical engineers rushed new technologies into production with unprecedented speed. While finding alternatives to burning fossil fuels is far more difficult, the business opportunities are also far larger. The market for low-carbon energy products will reach $500 billion by 2050, according to the Stern Review on the Economics of Climate Change, recently released by the British Treasury.

The effectiveness of any strategy on global warming will depend on how well it creates new markets. That much was learned from the Montreal Protocol. But perhaps the greatest lesson is also one of the simplest: when science shows us a looming environmental disaster, we need to act quickly and decisively, regardless of the economic or technical uncertainties. TR

David Rotman is the editor of Technology Review.

In the California lab of Infinera, cofounded by David Welch (left), chips called photonic integrated circuits (right) sit on a vinyl sheet. The larger chips can transmit 1.6 terabits of data per second; each of their gold patches contains 60 optical devices, built through repeated deposition and etching of semiconductor materials on wafers of indium phosphide. A single wafer (upper right, center of image) is lowered into a machine that applies chemicals as part of the etching process. On a test bench (lower right), finished chips are tested for the purity of their optical signals.

World's Fastest Optical Chip

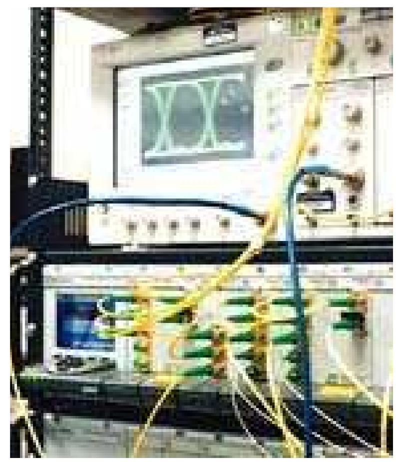
How Infinera packs dozens of optical components onto photonic integrated circuits for ultrafast optical networks. **By Kate Greene**

In his lab in Sunnyvale, CA, David Welch, cofounder of telecom startup Infinera, holds up a rigid two-centimeter-wide strip featuring four patterned, gold-colored rectangles. It's made of indium phosphide, a semiconductor prized for its optical properties. The chip's simple appearance belies its complex engineering and gives little hint that it could be the key to cheaply supplying the bandwidth demanded by a YouTube-addicted world.

The gadget is called a photonic integrated circuit, and it represents an important practical advance in optical data transmission. Since the early 1990s, such transmission has increasingly relied on a technique called wavelength division multiplexing (WDM). With WDM, data is encoded on as many as 80 laser beams, each having a different wavelength. Those beams are then combined for a trip down an optical fiber thinner than a human hair. At a node on the other end of the fiber, the beams are split into their constituent wavelengths, and the information is turned into the electrical signals that reach our computers.

The optical equipment required to do all this includes lasers that send light, multiplexers that split it up or recombine it, modulators that encode it with data, and detectors that receive it. Traditionally, these devices have been housed in their own little packages, each about the size of a pack of gum, and combinations of them were bulky, expensive, and sometimes unreliable. Infinera—founded in 2001 by veteran executives and technologists from optical-telecom leaders like Ciena

PHOTOGRAPHS BY EMILY NATHAN



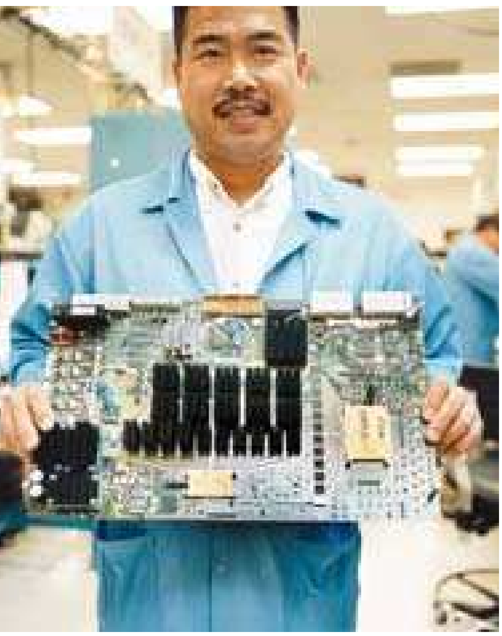
and JDS Uniphase—set out to put dozens of such components on a chip, the way electrical engineers combine transistors in an electronic integrated circuit. "What nobody had tried to do was essentially put an entire WDM system on a pair of chips [one to send, the other to receive], and nobody had tried to commercially manufacture it," says Welch. Infinera not only tried to do both but succeeded.

In 2004 the company introduced the first large-scale photonic integrated circuit—a chip with 50 nanoscale optical components patterned into its surface. Previously, other optical-chip manufacturers had managed to integrate only a few such devices on a single chip. The first Infinera device was capable of sending or receiving 100 gigabits of information per second. Now the company has demonstrated a 400-gigabit chip and is well along in the development of what it describes as the fastest optical chip in the world—a 1.6-terabit version that it expects to commercialize within several years. The four gold patches on the chip in Welch's hand contain an astonishing total of 240 patterned optical components.

Of course, despite the theoretical advantages of an "all-optical Internet," no network is based entirely on optics. Equipment at network nodes converts optical signals to electrical ones so it can clean them up and amplify them, or deliver them to a computer. Infinera's technology does this, too, passing some jobs off to microprocessors on a circuit board that will then transfer them back.

But the photonic integrated circuit reduced the cost and complexity of the conversion process. This advantage, in turn, allowed Infinera to promote a new network architecture—essentially, one with more network nodes. Other companies had tried to keep costs down by reducing the number of nodes, with their traditionally bulky optical devices.

Having more nodes means more flexibility to add access points and



Fourteen 100-gigabit photonic integrated circuits (above) sit in a plastic carrier for performance testing. Vetted chips are fitted into a device called a line card (left), which also contains silicon chips and other components. A waist-high optical networking unit containing four such line cards outperforms two of the refrigerator-size units in today's Internet switching stations.

easier maintenance and fault detection. It thus makes it easier to combine the benefits of optics and electronics. And the Infinera package—chips and circuit boards—take up one-fifth the space of conventional technology.

Late last year the Internet2 consortium—a group of more than 300 U.S. government, university, and corporate research centers that need high bandwidth to share everything from particle-physics data to medical images—began deploying a new optical network that uses Infinera's systems. "Infinera's technology is unique," says Steve Cotter, director of network services at Internet2. "Instead of trying to avoid optical-electrical transitions, they made them cost effective."

Photonic Fabrication

Making the Infinera chips is no simple task. Optical devices are three-dimensional structures, far more challenging to manufacture than two-dimensional silicon transistors. Making the lasers, detectors, modulators, and other components of the finished chip requires repeatedly depositing and etching away many thin layers of different materials, such as indium gallium arsenide and indium phosphide.

Infinera's process starts with a wafer of indium phosphide. The wafer moves along an assembly line, where it is coated with a syrupy chemical called photoresist. Ultraviolet light shines through a mask with stencil-like designs and irradiates the photoresist, effectively "developing" intricate patterns that allow some semiconductor material to stay on the wafer and some to be etched away.

At a high level, it's the same as the photolithography that companies like Intel use to make silicon microprocessors for your PC. But there's an important difference. "In an Intel chip, it's all silicon. In optics you use various semiconductors with various functions," Welch says. And the indium phosphide wafers go through many more rounds of deposition and etching than silicon wafers do. Infinera is tight-lipped about the details of its manufacturing process, which was designed with the help of engineers experienced in such tasks as manufacturing silicon microchips and mass-producing light-emitting diodes. Welch says the company has exclusive patents on key aspects of the technology for placing large numbers of devices on indium phosphide wafers.

The 1.6-terabit chip differs from the 100-gigabit version largely in the number of devices patterned onto it. Each 100-gigabit chips contains, among other components, 10 lasers, 10 detectors, 10 modulators (which encode data by switching light on and off), and 10 waveguides that direct photons into a multiplexer. The 1.6-terabit chip's 240 components include 40 lasers, 40 detectors, 40 modulators, and 40 channels. And each modulator encodes data four times as fast.

After the wafers come off the line, they are sliced into chips—several hundred of them. Finally, the chips are tested for potential malfunctions, combined with electronic chips built by Infinera on a device called a line card, and installed in optical networking units for shipment.

Demand for Internet video and voice services is exploding, threatening to overwhelm the typical broadband connection, which transmits between one and six megabits per second. "We're all thinking that people will need 25, 50, or 100 megabits," Welch says. To meet that demand, Internet companies will have to pack more equipment into already overcrowded switching stations. "With Internet traffic growing at 60 to 100 percent per year, you can't keep installing refrigerator-size racks in the basement," Welch says. "Photonic integration becomes the technology that enables the Internet to grow." TR

Its coming...

2007

Technology Awards Competition

The 4th Annual MITX Technology Awards recognizes innovative technologies developed in New England as well as the individuals and organizations that have made significant contributions to advance innovation in our region.

- CALL FOR ENTRIES LAUNCH - Tuesday, February 13th
- SUBMISSION DEADLINE - Friday, March 30th
- AWARDS CEREMONY - Tuesday, June 5th

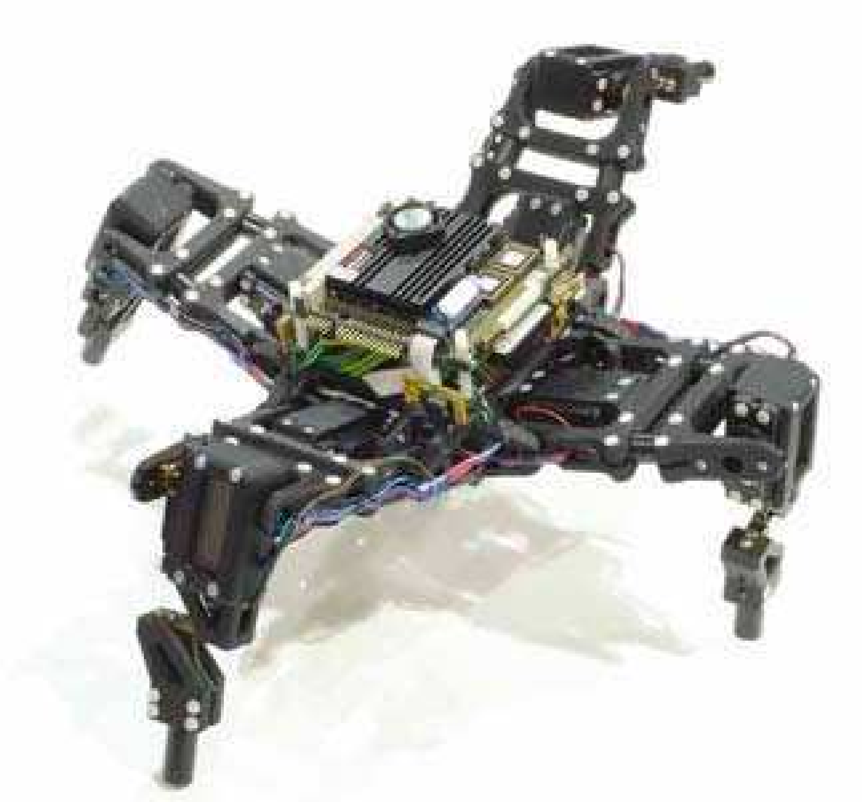
MASSACHUSETTS INNOVATION & TECHNOLOGY EXCHANGE

WHAT'S NEXT.

www.mitx.org
awards@mitx.org
call: 617.871.2155

From the Labs

Current research in information technology, nanotechnology, and biotechnology



A robot, which hasn't been programmed to walk, teaches itself how to move effectively and how to adjust its gait if it is damaged.

INFORMATION TECHNOLOGY

Resilient Robots

Self-aware machines are able to assess injuries and make adjustments

SOURCE: "Resilient Machines through Continuous Self-Modeling"
Josh Bongard et al.
Science 314: 1118–1121

RESULTS: By constantly monitoring its own structure, a four-legged robot built by Josh Bongard, a professor of computer science at the University of Vermont, and colleagues at Cornell University can tell if it has damaged or lost a limb and adapt its gait accordingly.

WHY IT MATTERS: Robots are useful for exploring environments that are too harsh for humans—unless they suffer damage and can't compensate for it. Previous recovery schemes for damaged robots relied on built-in redundancy such as extra limbs, or preprogrammed contingency plans that anticipated certain failures. Bongard designed a robot that constantly and autonomously monitors itself, adjusting to damage like joint separation or disappearance of a limb. His approach could make robots more useful in harsh environments.

METHODS: The robot is equipped with sensors and actuators that collect information about the relative position of its parts. Based on the sensor data, the robot's onboard computer creates mathematical models of the state of its body. If one of the robot's limbs is damaged, data from the sensors can be used to generate a new model. A separate algorithm runs simulations of possible gaits, searching for the most efficient one for the damaged robot. The process usually takes about eight hours.

NEXT STEPS: Bongard plans to apply his algorithms to a collection of robots. Drawing on the experiences of others in a group could speed up an individual robot's recovery rate. A damaged robot would send out a query to the other robots in the group, essentially asking if they'd encountered the same injury and how they adjusted.

Spinning Light

A system combining a magnetic material and a semiconductor could lead to spintronic devices that pack more data into beams of light

SOURCE: "Reconstruction Control of Magnetic Properties during Epitaxial Growth of Ferromagnetic $Mn_{3-\gamma}Ga$ on Wurtzite GaN(0001)"
Erdong Lu et al.
Physical Review Letters 97: 146101

RESULTS: Arthur Smith, a professor of physics at Ohio University, and postdoc Erdong Lu have grown manganese gallium, a metal, on gallium nitride, a semiconductor commonly used to make blue lasers and light-emitting diodes. Smith and Lu believe that the new material could lead to room-temperature lasers that exploit the spin of electrons (spintronics).

WHY IT MATTERS: Lasers based on spintronics, rather than on conventional electronics, have the potential

CORNELL UNIVERSITY

Advertisement

Executive Education Resource for Technology Leaders

Short-Term Investment Equals Long-Term Growth

Do you want to broaden your knowledge base? How do you know which executive education or Web-based MBA program is right for you? *Technology Review*'s program directory and online resource offers expert tips, articles, and details about top programs to help guide your decision toward investing in your personal growth and professional success.

Take the initiative! Access helpful articles and tips and view our online directory at:
http://www.technologyreview.com/resources/execed/

PROGRAM DIRECTORY

BOSTON UNIVERSITY SCHOOL of Management

Boston University Executive MBA Program

If you have 10 or more years of experience and are looking to take your career to that next level, the Boston University Executive MBA (EMBA) Program might be right for you. We are recognized as the #1 EMBA program in New England; you will complete your MBA in just 17 months, without interrupting your career. This program is for highly motivated professionals who are looking to set themselves apart in their organizations.

www.bu.edu/emba

MITSloan MANAGEMENT

MIT Sloan Executive Education

MIT Sloan Executive Education provides senior executives and managers with the tools and frameworks to drive innovation and turn today's good ideas into tomorrow's successful products and services. From technology strategy to system dynamics, financial engineering to life sciences, we offer cutting-edge programs that reflect the depth and expertise of our faculty and MIT's research distinction.

http://mitsloan.mit.edu/tr

Polytechnic UNIVERSITY
CELEBRATING 150 YEARS OF POLYTHINKING

MOT-TIM EXECUTIVE MASTER'S PROGRAMS

Manage for Tomorrow.

Polytechnic University Executive Master's Programs

Based in New York City and Westchester, NY, Polytechnic University's fast-track executive master's programs in Management of Technology and Telecommunications & Information Management enable professionals to move beyond pure technology and become effective managers of innovation. Participants gain knowledge increasingly valuable to firms and not easily outsourced. Join us for a summer info session. Get complete details at:

http://www.mot-tim.poly.edu

To list your program in the Executive Education Directory, e-mail Maureen Elmaleh at maureen.elmaleh@technologyreview.com or call, 212-419-2823.

to increase bandwidth in optical networks. Currently, data is encoded as the frequency and phase characteristics of a beam of light. In a spintronic laser, however, electrons with a certain spin can create photons with a corresponding spin, resulting in polarized light. Using polarization to encode a light beam with data could increase the amount of information it can carry. But until now, researchers have lacked materials suitable for making spintronic lasers.

METHODS: Using standard processes, Smith and Lu deposited a thin film of manganese gallium onto gallium nitride. Reflection high-energy electron diffraction revealed a smooth interface between the two materials—a necessity if electrons are to maintain their spin as they travel into the light-emitting semiconductor.

NEXT STEPS: Researchers must determine whether the spin characteristics of the electrons are indeed preserved. They must also test the material's light-emitting properties to determine how well the spin of electrons translates into polarized light.

NANOTECHNOLOGY

Morphing Materials

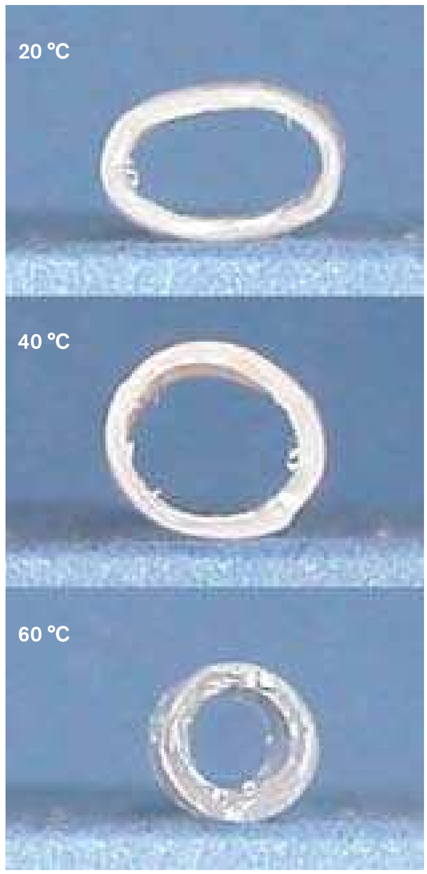
New shape-memory polymers can take on three successive shapes

SOURCE: "Polymeric Triple-Shape Materials"
Ingo Bellin et al.
Proceedings of the National Academy of Sciences 103(48): 18043–18047

RESULTS: Researchers at MIT and the GKSS Research Center in Germany have engineered polymers that can be programmed to sequentially take on three different predefined shapes in response to changes in temperature.

WHY IT MATTERS: Existing shape-memory polymers can assume only two shapes each. The addition of a third shape could enable, say, an arterial stent that could be inserted into an artery in a collapsed form, induced to open once in place, and later shrunk for removal. The researchers demonstrated such an intelligent tube, along with a structure that could be used in device manufacture to connect difficult-to-access parts.

METHODS: Each of the new materials is a polymer network consisting of two different cross-linked segments



A new polymer morphs from one pre-programmed shape to two others: as the flattened tube (top) is heated, it opens up (middle); heating it further makes it shrink.

GKSS RESEARCH CENTER

that respond to temperature differently. The researchers first cast the material into its final shape—such as the shrunken version of the stent—using a standard plastic-molding technique. They then use a precise sequence of heating and cooling steps to "program" the other two shapes, taking advantage of the material's different responses to different temperatures. Heating the material in two steps makes it revert to its intermediate, and finally to its original, shape.

NEXT STEPS: The researchers must demonstrate that the materials are safe enough to be used in medical applications. They are also developing fastener materials that could be useful in manufacturing.

Invisible Transistors

A novel method could lead to see-through displays for windshields

SOURCE: "High-Performance Transparent Inorganic-Organic Hybrid Thin-Film N-Type Transistors"
Lian Wang et al.
Nature Materials 5(11): 893–900

RESULTS: Northwestern University researchers have fabricated high-performance, transparent thin-film transistors (TFTs) using a low-cost, low-temperature method. They use indium oxide as both a semiconductor and a conductor, combining the inorganic material with organic insulators on top of a transparent substrate. The resulting transistors perform nearly as well as the much more expensive polysilicon transistors used to control pixels in high-end TVs and computer monitors.

WHY IT MATTERS: The new TFTs could replace the opaque transistors used to control pixels in digital displays. Because the low-temperature method can deposit transistors on flexible plastics, it could lead to see-through displays affixed to curved surfaces such as windshields and helmet visors. The method is also cheap enough, and easy enough to adapt for large-scale manufacturing, that it could make such displays affordable.

METHODS: On glass that's been coated with a transparent electrode, the researchers deposit the organic insulating materials, which form a multilayered lattice. To deposit the indium oxide, the researchers use a standard technique called ion-assisted deposition, in which an ion beam con-

trols the crystallization and adhesion of the oxide. Changing the oxygen pressure during the process varies the conductivity of the indium oxide, which can thus be used as a semiconductor in one part of the device and as a conductor in other parts.

NEXT STEPS: Negotiations for licensing the technology have begun. Prototype displays could be ready within 18 months. The researchers hope to improve the performance of the transistors so that they could serve as processors or memory cells.

BIOTECHNOLOGY

Rerouting Brain Circuits with Implanted Chips

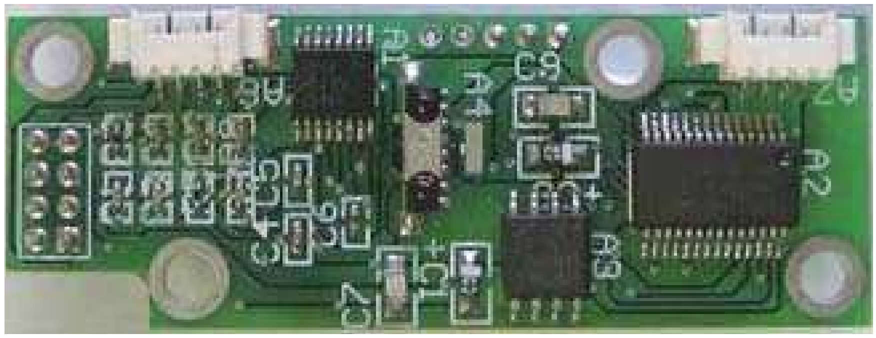
A chip being tested in monkeys could one day reconnect areas of a damaged brain

SOURCE: "Long-Term Motor Cortex Plasticity Induced by an Electronic Neural Implant"
Andrew Jackson et al.
Nature 444(7115): 56–60

RESULTS: Researchers from the University of Washington in Seattle showed for the first time in live animals that an implantable device could record signals from one part of the brain and transmit them to another part, reshaping neural connections in the process.

WHY IT MATTERS: In stroke and spinal-cord injuries, neural circuits that mediate language or movement may be damaged, leaving patients with profound disabilities. The Washington research is a significant first step in developing neural prosthetics that can help bridge broken connections.

METHODS: Tiny wire electrodes were surgically implanted into a monkey's motor cortex. (Neurons in this area are active when an animal makes a voluntary movement.) The wires record the activity of nearby cells and relay their signals to a small printed circuit board for amplification and processing. The neural activity is converted to electric pulses, which stimulate cells at a neighboring motor-cortex site. The entire apparatus, about half the size of a deck of cards, is encased in titanium and attached to the monkey's head, where it doesn't interfere with the animal's normal daily activities.



An implantable neurochip circuit board, hooked up to tiny wires, can be used to artificially connect two parts of the brain.

A. JACKSON, J. MAVOORI, E. FETZ

NEXT STEPS: Project leader Eberhard Fetz and his colleagues hope to show that a similar device could transmit neural signals from the brain directly to the spinal cord or to a muscle, bypassing areas of neurological injury. The researchers have shown that electrically stimulating certain cells in the spinal cord can elicit specific movements, such as grasping.

Wine Component Boosts Exercise Capacity in Mice

Resveratrol allows treated mice to run for twice as long as untreated ones

SOURCE: "Resveratrol Improves Mitochondrial Function and Protects against Metabolic Disease by Activating SIRT1 and PGC-1α"
Marie Lagouge et al.
Cell online, November 16, 2006

RESULTS: Researchers at France's University Louis Pasteur, Strasbourg, and at Sirtris Pharmaceuticals have shown that resveratrol, a chemical component of red wine that has already been linked to longevity, protects mice against diet-induced obesity and insulin resistance and boosts their endurance, allowing them to run for twice as long as untreated animals before becoming exhausted. The researchers found that mice treated with resveratrol also had large, highly active mitochondria, the subcellular structures that convert nutrients into energy in almost all plants and animals. This effect was linked to activation of a gene called SIRT1, the mammalian equivalent of a gene known to influence life span in yeast.

WHY IT MATTERS: The findings may indicate the mechanism behind resveratrol's life-extending effects: activating SIRT1 to boost metabolic function. If scientists can understand how to regulate the biochemical pathway that causes aging, they may be able to design drugs that can stop the diseases of old age.

METHODS: Mice fed a high-fat diet were given high doses of resveratrol (either 200 or 400 milligrams per kilogram of body weight, or the equivalent of about 8,000 to 16,000 glasses of red wine). The researchers then tested the resting metabolism, exercise capacity, and insulin sensitivity of the mice. They also used electron microscopy to study the size of the mice's mitochondria and calculated differences in the expression of mitochondria-related genes in treated and nontreated mice.

NEXT STEPS: Sirtris Pharmaceuticals is conducting a clinical trial of a resveratrol-like compound intended to treat type II diabetes. TR

Call for Nominations

What will the world look like in five, 10, or 30 years? Who are the leading young innovators already laying the foundations for that future? Help us find the next generation of technology pioneers and tell their stories!

Nominations are now open for the 2007 edition of the TR35, *Technology Review*'s list of 35 young people whose contributions to emerging technologies are poised to profoundly change our world. Nominees should not turn 35 before October 1, 2007, and their work should exemplify the spirit of innovation in fields such as biotechnology, computing, energy, medicine, nanotechnology, telecommunications, and transportation. *Technology Review* will feature all 35 in a special September/October 2007 issue and recognize them at our annual Emerging Technologies Conference at MIT, September 25-27, 2007.

The deadline for nominations is March 1, 2007.
To nominate, visit:
www.technologyreview.com/tr35/nominate.aspx

Alumni-to-Alumni Directory

Recruitment

EDELMAN & ASSOCIATES
Executive search and technical recruiting for software, biotech, pharmaceutical, and other high-technology companies.

Paul Edelman '78
paul@edeltech.com
508-947-5300

To see a listing of current searches, please visit us at www.edeltech.com.

For confidential consideration, send your résumé to paul@edeltech.com.

EXPERIENCED SYSTEM SIMULATION/MODELING/ MONTE CARLO
Areas: technology, gov't, manufacturing, finance, defense
Contact: peft@alum.mit.edu

Classifieds

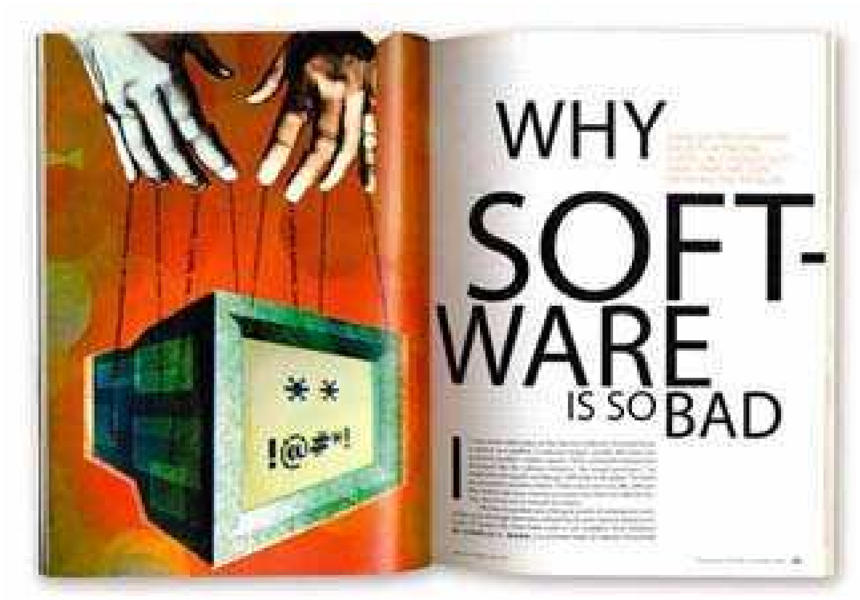
A BETTER MOUSETRAP!
MIT-educated technologists will invent and develop it for you.
781-862-0200 www.weinvent.com

SMART IS SEXY
Date fellow graduates and faculty of MIT, the Ivies, Seven Sisters and a few others.
The Right Stuff
800-988-5288
www.rightstuffdating.com

CLASSIFIED & ALUMNI DIRECTORY ADVERTISING
For more information on classified or recruitment display advertising, contact:
advertising@technologyreview.com

The Trouble with Software

By Katherine Bourzac



When you drive a new car off the lot, you can assume it won't need repairs for a long time (unless you crash it). But when you install a Microsoft program on your computer, you assume that your next step will be to download security patches and bug fixes. A July 2002 feature in these pages asked why software is so bad and wondered whether programmers shouldn't be held to the same quality standards as other workers equally critical to our industrial civilization, such as mechanical, electrical, and civil engineers.

That unresolved question has inspired one of software's leading lights to propose a radical answer. As Scott Rosenberg reports in this issue *(see "Anything You Can Do, I Can Do Meta," p. 36)*, Charles Simonyi, Microsoft's chief architect during its formative years, has started a company dedicated to developing an entirely new approach to writing code. Though it's unclear whether he'll succeed, it is clear, as Charles C. Mann wrote five years ago, that the software business has singular problems.

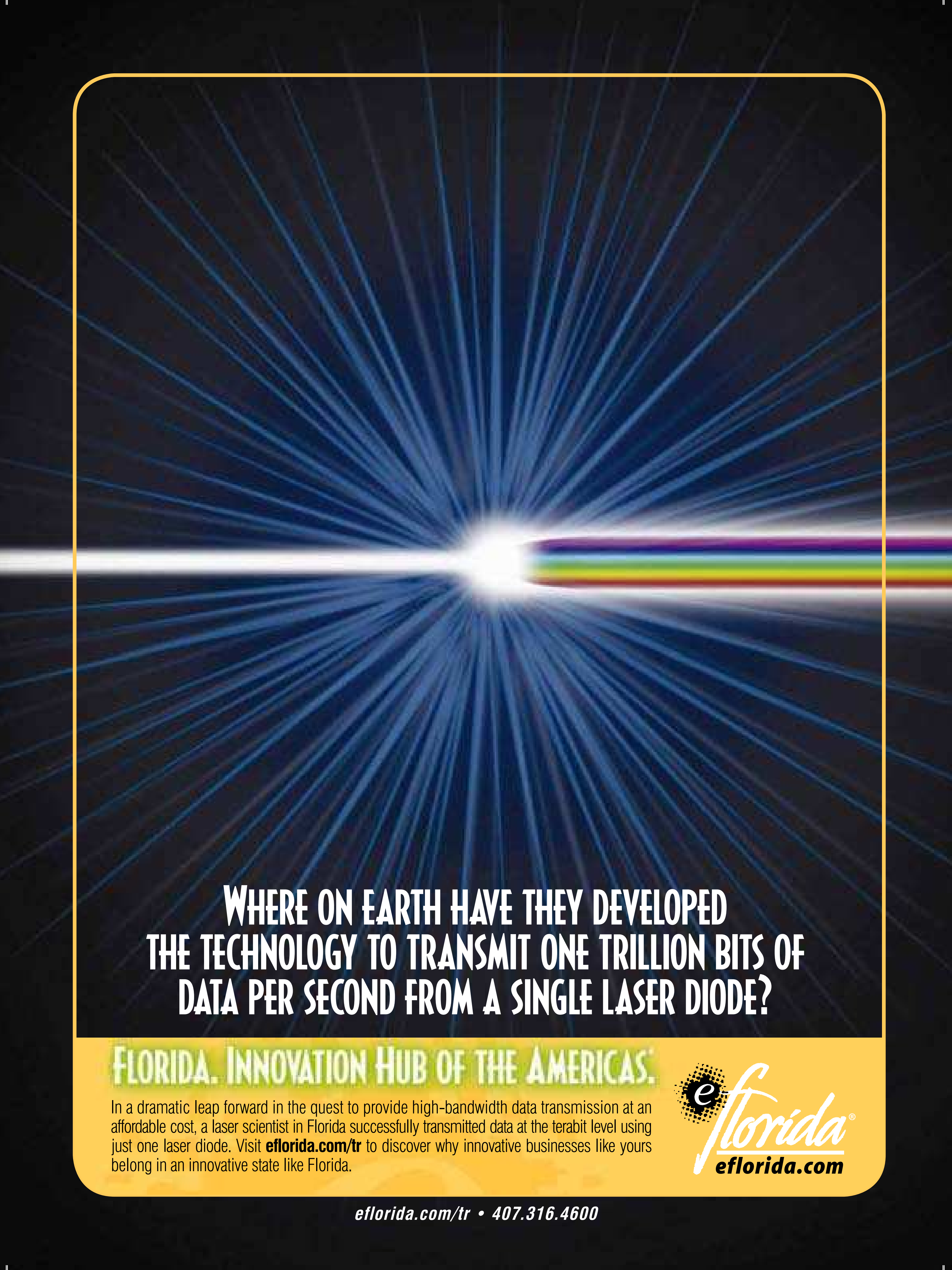
Programming experts tend to agree that … disasters are distressingly common. Consider the Mars Climate Orbiter and the Polar Lander, both destroyed in 1999 by familiar, readily prevented coding errors. But some argue that software simply cannot be judged, measured, and improved in the same way as other engineering products. "It's just a fact that there are things that other engineers can do that we can't do," says Shari Pfleeger, a senior researcher at the Rand think tank in Washington, DC, and author of the 1998 volume Software Engineering: Theory and Practice. *If a bridge survives a 500-kilogram weight and a 50,000-kilogram weight, Pfleeger notes, engineers can assume that it will bear all the values between. With software, she says, "I can't make that assumption—I can't interpolate."*

Moreover, software makers labor under extraordinary demands. Ford and General Motors have been manufacturing the same product—a four-wheeled box with an internal-combustion engine—for decades. In consequence, says Charles H. Connell, former principal engineer of Lotus Development (now part of IBM), they have been able to improve their products incrementally. But software companies are constantly asked to create products—Web browsers in the early 1990s, new cell-phone interfaces today—unlike anything seen before. "It's like a car manufacturer saying, 'This year we're going to make a rocket ship instead of a car,'" Connell says. "Of course they'll have problems." …

It is difficult to overemphasize the uniqueness of software's problems. When automotive engineers discuss the cars on the market, they don't say that vehicles today are no better than they were ten or fifteen years ago. The same is true for aeronautical engineers: nobody claims that Boeing or Airbus makes lousy planes. Nor do electrical engineers complain that chips and circuitry aren't improving. As the engineering historian Henry Petroski suggested in his 1992 book The Evolution of Useful Things, *continual refinement is the usual rule in technology. Engineers constantly notice shortcomings in their designs and fix them little by little, a process Petroski wryly described as "form follows failure." As a result, products incrementally improve.*

Software, alas, seems different. One would expect a 45-million-line program like Windows XP, Microsoft's newest operating system, to have a few bugs. And software engineering is a newer discipline than mechanical or electrical engineering; the first real programs were created only 50 years ago. But what's surprising—astonishing, in fact—is that many software engineers believe that software quality is not improving. If anything, they say, it's getting worse. It's as if the cars Detroit produced in 2002 were less reliable than those built in 1982. TR

Technology Review (ISSN 1099-274X), Reg. U.S. Patent Office, is published bimonthly by the Massachusetts Institute of Technology. Entire contents ©2007. The editors seek diverse views, and authors' opinions do not represent the official policies of their institutions or those of MIT. Printed by Brown Printing Company, Waseca, MN. Periodicals postage paid at Boston, MA, and additional mailing offices. Postmaster: send address changes to Technology Review, Subscription Services Dept., PO Box 420005, Palm Coast, FL 32142, or via the Internet at www.technologyreview.com/customerservice/. Basic subscription rates: $34 per year within the United States; in all other countries, US$47. Publication Mail Agreement Number 40621028. Send undeliverable Canadian copies to PO Box 1051 Fort Erie, ON L2A 6C7. Printed in U.S.A. ABC audited



WHERE ON EARTH HAVE THEY DEVELOPED THE TECHNOLOGY TO TRANSMIT ONE TRILLION BITS OF DATA PER SECOND FROM A SINGLE LASER DIODE?
FLORIDA. INNOVATION HUB OF THE AMERICAS.
In a dramatic leap forward in the quest to provide high-bandwidth data transmission at an affordable cost, a laser scientist in Florida successfully transmitted data at the terabit level using just one laser diode. Visit **eflorida.com/tr** to discover why innovative businesses like yours belong in an innovative state like Florida.
eflorida®
eflorida.com
eflorida.com/tr • 407.316.4600